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Improving Central Heating Plant Performance at the Defense Construction Supply Center (DCSC)

Advanced Operation and Maintenance Methods

by
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Foreword

This study was conducted for Defense Construction Supply Center (DCSC) under Military Interdepartmental Purchase Request (MIPR) No. SC700-88-0016. The technical monitor was MAJ Robert Genton, DCSC-W.

The work was performed by the Energy and Utility Systems Division (FE) of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). Donald F. Fournier is Acting Chief, CECER-FE, and Dr. David M. Joncich is Acting Chief, CECER-FL. The USACERL technical editor was William J. Wolfe, Information Management Office.

LTC David J. Rehbein is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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1 Introduction

Background

Air pollution emissions tests performed by the U.S. Army Environmental Hygiene Agency (USAEHA) in February 1987 confirmed the gradual deterioration in efficiency and reliability of the central heating plant (CHP) at the Defense Construction Supply Center (DCSC), Columbus, OH. These tests showed the particulate emissions to be marginally acceptable, but still well above the capabilities of the equipment. USAEHA identified broken discharge electrodes, warped collection plates, and low flue gas inlet temperatures as possible causes for poor electrostatic precipitator (ESP) performance. Additional information indicated excessive coal fines and high excess air as potential causes of the combustion equipment's poor performance, which in turn reduced ESP efficiency.

Although DCSC performed the required repairs on the ESP, improved coal specifications, and tried to reduce air infiltration, the repairs did not significantly improve combustion system operation. Consequently, DCSC contracted USACERL to use newly developed, advanced operation and maintenance methods to improve the performance of its combustion system.

Objectives

The objectives of this study were to take a system-wide approach to investigate the causes for the poor performance of the DCSC CHP, and to recommend both short- and long-term improvements to plant performance.

Approach

The combustion and air pollution compliance problems were first investigated by reviewing the 1987 USAEHA emissions tests to identify potential problem areas and to focus the efforts of this project.

The fireside portion of the heating system was then evaluated to identify potential problems in operation and physical condition of the equipment. This evaluation included stokers, furnace, convective sections, combustion controls, coal specifications, and air pollution control equipment.

Several short-term, economical improvements for increasing combustion and pollution control efficiency were identified. A series of combustion and emissions tests were made to document the effectiveness of these improvements. The tests concluded with an official Ohio Environmental Protection Agency (OEPA) compliance test to show that the plant could meet and maintain the state's air pollution control requirements. A training workshop was developed and given to plant personnel to help them maintain optimum CHP operation. Several long-term improvements were identified and recommended to help reduce CHP maintenance costs and extend the plant's productive and efficient life.

Mode of Technology Transfer

It is recommended that the operation and maintenance concepts for combustion and air pollution control equipment be incorporated into DCSC central heating plant procedures. It is also recommended that these concepts be incorporated into Army Technical Manual (TM) 5-650, *Repairs and Utilities: Central Boiler Plants* (Headquarters, U.S. Army Corps of Engineers [HQUSACE], Washington, DC, 13 October 1989).

2 Site Description

Thermal energy needs for DCSC are provided primarily by high temperature hot water (HTHW) produced by a coal-fired central heating plant. Air pollution control for the central heating plant is provided by an electrostatic precipitator.

Thermal Energy Use

DCSC's primary function is to provide administrative, distribution, and storage support for the Department of Defense. The installation has about 6.6 million sq ft of building area (1 sq ft = 0.093 m^2). Of this, about 3.5 million sq ft is heated by the central heating plant, 100,000 sq ft is heated by other fuels, and 3 million sq ft is unheated.

One hundred percent of the thermal energy provided by the CHP is consumed for space heating. This energy is distributed as HTHW through about 7 miles of pipeline that supplies HTHW to 26 steam generators and eight low temperature hot water heat exchangers (1 mi = 1.61 km). The primary heating media is steam that is distributed within the buildings through about 18 miles of steam pipeline. The building condensate return system is about 18 miles of pipeline containing 1,850 steam traps. Because there is no heating demand during the summer months, the central heating plant is shut down from May through October each year. The typical fuel consumption for DCSC is about 10,600 tons of coal per year (1 ton = 907.18 kg). Table 1 shows the monthly coal use as a percent of the annual use.

Table 1. Monthly coal use (percentage of annual use).

Season	Fuel Use (%)
January	24
February	20
March	17
April	3
May	0
June	0
July	0
August	0
September	0
October	0
November	13
December	23

Central Heating Plant

Figure 1 shows a schematic representation of the central heating plant combustion air flow system. The plant contains three high temperature water generators (HTWG), all rated at 70 MBtu/hr output. All were manufactured by Riley Stoker, and installed in the 1960s. The units burn bitu-

minous coal with a sulfur content of between 2 and 3 percent. Air pollution control is accomplished by individual multiple cyclone collectors and common electrostatic precipitators.

Figures 2 and 3 show the combustion air flow through an individual HTWG. Each HTWG draws combustion air from a vent located above the roof of the plant (1 ft = 0.305 m). The combustion air is drawn, by a forced draft (FD) fan, through an air preheater located at the HTWG outlet (breeching). The air preheater is simply a vertical enclosure around the outside of the breeching containing several baffle plates.

The heated air then enters an air plenum (windbox) that distributes the air under the stoker grates. Additional combustion air is introduced as overfire air in the furnace chamber to increase turbulence and retention time, which in turn improves combustion efficiency. The overfire air is provided by a separate fan that pulls air from the HTWG house operating floor.

The combustion flue gases are then pulled by an induced draft fan through the air preheater and a multiple cyclone collector (mechanical collector). The multiple cyclone collectors remove fly-ash particles from the flue gas to protect the induced draft fan and reduce particulate emissions.

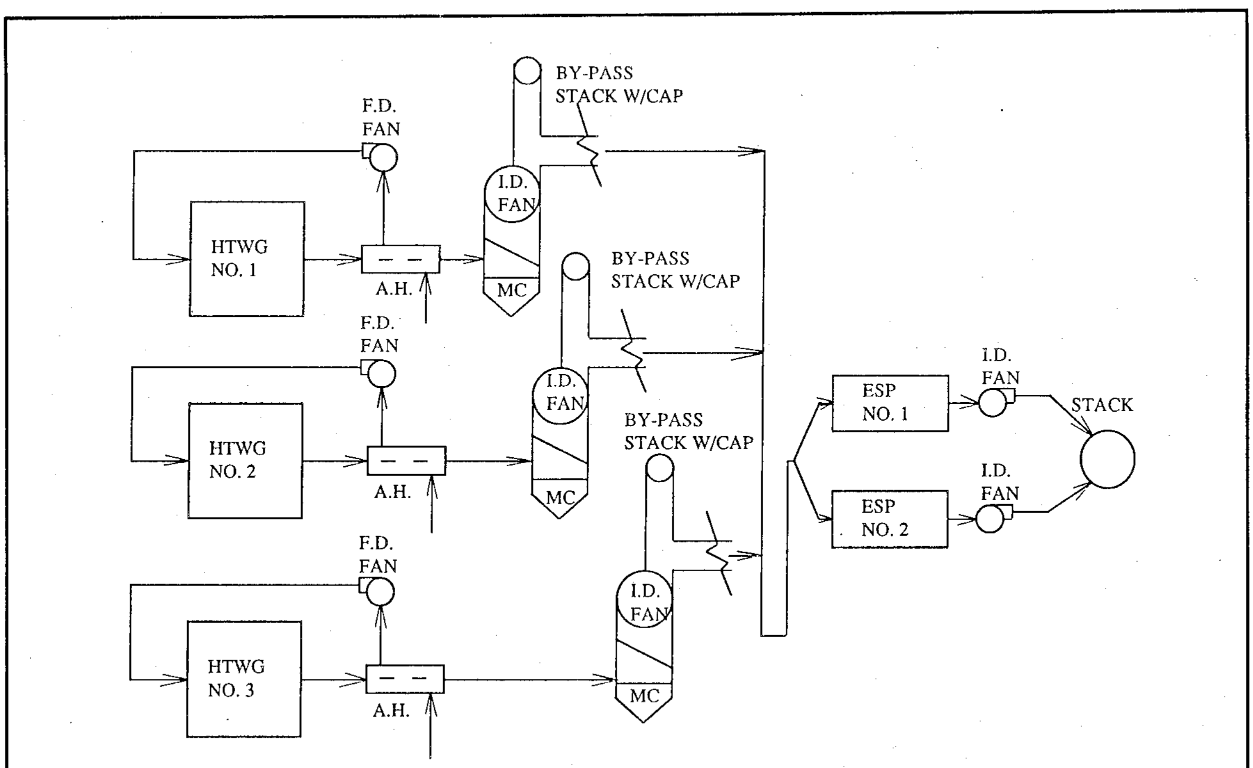

Figure 1. CHP combustion airflow schematic.

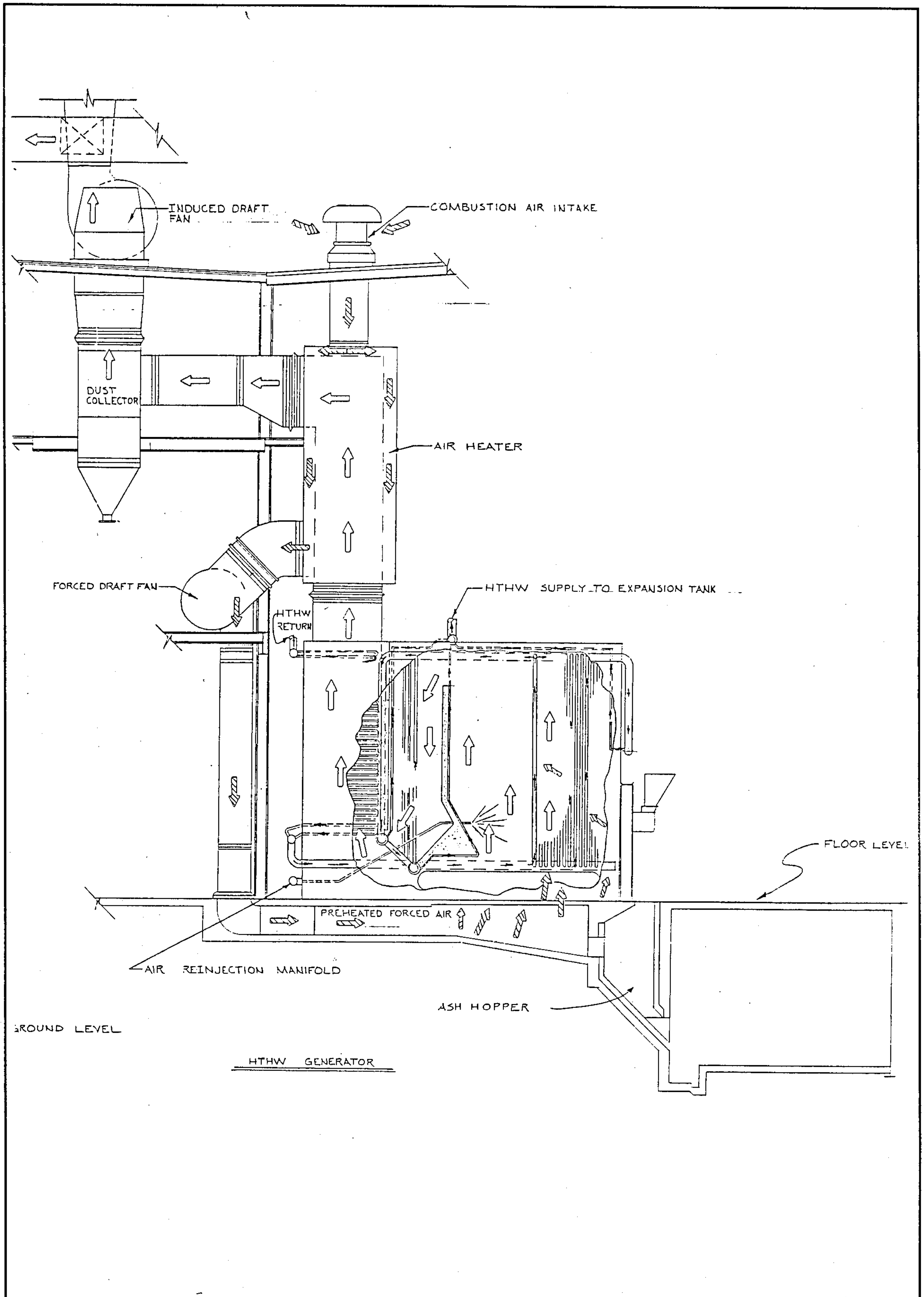

Figure 2. HTWG combustion air flow schematic—HTHW generator.

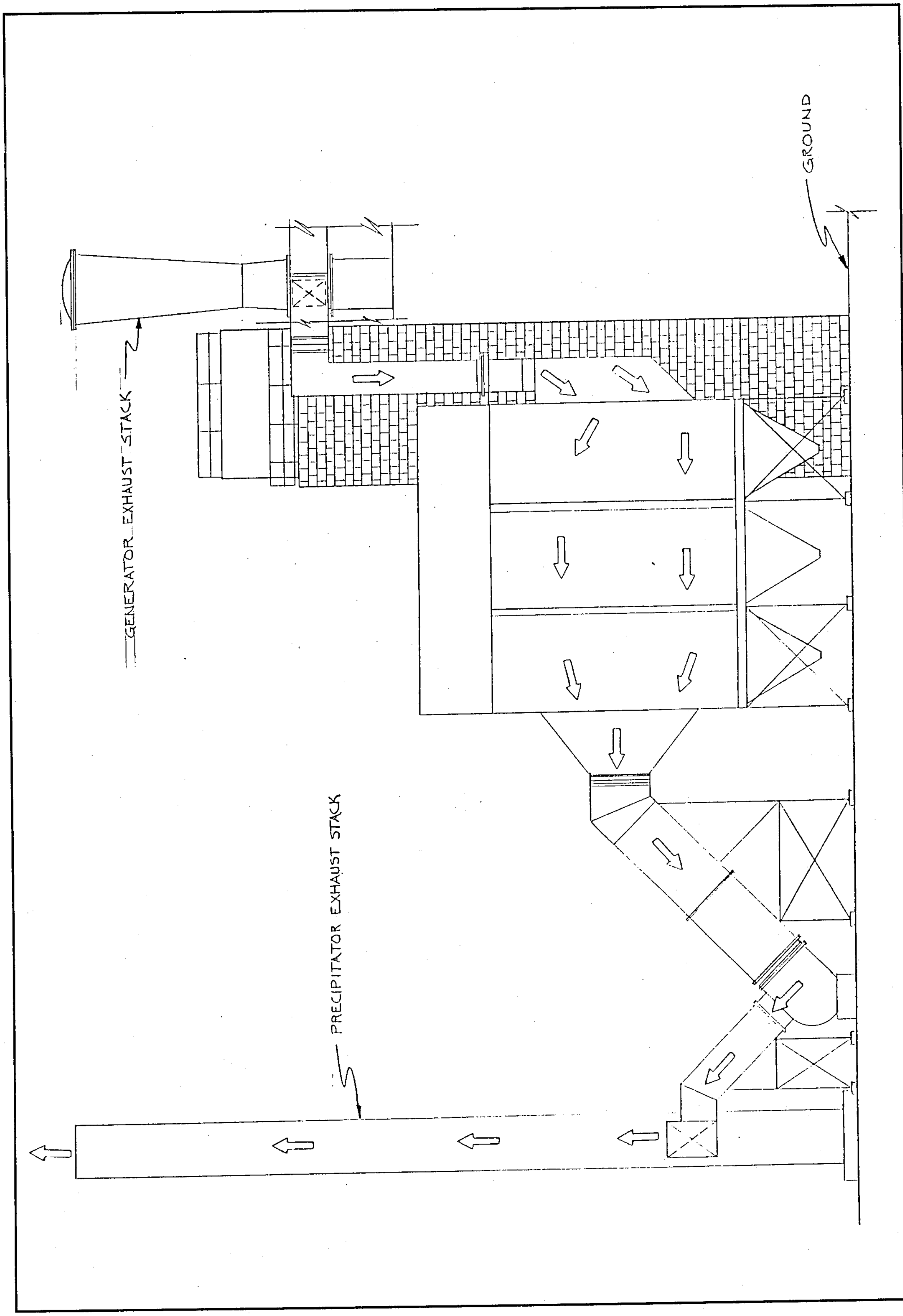

Figure 3. HTWG combustion air flow schematic—exhaust stack.

At this point, the flue gas from all the HTWG are pulled through a common breeching by a common induced draft fan that directs the flue gas to an ESP system. The ESP system consists of two Precipitator Pollution Control, Inc. units rated at 125,000 ACFM each. Only one unit is used during normal operation. Each HTWG also has a bypass stack that is used when the ESP system requires shut down.

3 System Review and Inspection

A thorough investigation was made of the plant's operation and maintenance condition. The objective of this investigation was to identify areas of improvement and optimize the equipment to ensure continued compliance with OEPA regulations. The investigation included review of past emission tests and field inspections of the combustion and air pollution control equipment.

Past USAEHA Emission Tests

In accordance with DCSC's air pollution source permit with the Ohio Environmental Protection Agency, USAEHA performed a set of particulate and sulfur dioxide emissions tests on 9-13 February 1987 (Stationary Air Pollution Source Assessment No. 42-21-0556-87). Of the six tests done, three failed the particulate emission standards and none failed the sulfur oxides emission standard. Table 2 summarizes the results of these tests.

The first three tests were conducted with one ESP on-line and the next three with both ESPs on-line. The use of both ESPs improved the emission slightly; however, one test still failed and the others passed by only a narrow margin. The test information indicated possible problems with the combustion system and the ESP.

Table 2. Emission test results.

	Particulate Emission Rates (lb/MBtu)				SO_2 Emission Rates (lb/MBtu) Based on AP-42	
Test No.	Based on F_d-Factor	Based on F_c-Factor	Based on Feed Rate	Standard	Method	Standard
1	0.17	0.18	0.18	0.16	1.33	1.5
2	0.37	0.38	0.45	0.16	1.24	1.5
3	0.10	0.11	0.11	0.16	1.18	1.5
4	0.14	0.15	0.17	0.16	1.30	1.5
5	0.24	0.25	0.26	0.16	1.21	1.5
6	0.12	0.12	0.12	0.16	1.13	1.5

Combustion system operation

Table 3 shows the generator operating capacities during the tests. The average generator capacity during the tests was 57 percent, indicating a light load on the generators. Although HTWGs are typically less efficient at this lower operating level, the air pollution control devices should have been able to handle the slight increase in particulate emissions, assuming that the generators were operating reasonably well. No unusual combustion conditions were noted in the USAEHA tests.

Some poor combustion conditions could have occurred based on the coal analysis shown in Table 4. The coal quality is within the required coal specifications with the exception of coal size, shown at the bottom of the table. Generator no. 2 consistently showed a higher percentage of fines than generator no. 3. This would indicate problems with coal segregation in the coal handling system or storage procedures.

Coal fines tend to be blown out of the combustion chamber before they can be completely combusted. In addition to increasing particulate loading on the air pollution control devices, the high carbon content of these particles reduced the performance of the ESP. Low resistivity fly ash particle dissipate their electrical charges rapidly after reaching the dust layer on the collection plates. This means that there is only a slight charge holding the dust layer to the collection plates. When rapped, some of this dust is re-dispersed into the moving gas stream and emitted out the stack. This condition appears as a short-term "puff." Such puffing was noted by USAEHA during the tests.

Table 3. Heat loads.

Test No.	Generator No.	Coal Feed Rate (lb/hr)	Heat Input (MBtu/hr)	% of Maximum Capacity
1	2	3,200	42.6	60.9
1	3	3,300	43.7	62.4
2	2	2,900	38.3	54.7
2	3	2,900	39.0	55.7
3	2	3,600	44.3	63.3
3	3	3,200	43.9	62.7
4	2	3,100	39.7	56.7
4	3	2,900	39.4	56.3
5	2	2,800	35.8	51.1
5	3	2,300	31.0	44.3
6	2	2,700	34.3	49.0
6	3	3,200	42.7	61.0

Table 4. Coal analysis.

Test Number	1	1	2	2	3	3	4	4	5	5	6	6
Generator Number	2	3	2	3	2	3	2	3	2	3	2	3
Moisture (%)												
HTWG specification	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Test coal as received	4.91	4.75	5.43	4.59	10.22	4.11	6.38	4.75	6.47	4.52	6.66	3.67
Carbon (%)												
HTWG specification	65.72	65.72	65.72	65.72	65.72	65.72	65.72	65.72	65.72	65.72	65.72	65.72
Test coal as received	73.25	69.01	71.23	66.88	69.24	71.58	67.25	70.82	71.92	73.31	71.58	73.99
Test coal dry basis	77.03	72.57	75.63	69.61	77.14	74.56	72.15	74.47	76.42	76.36	76.80	76.26
Hydrogen (%)												
HTWG specification	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60
Test coal as received	4.81	4.95	3.44	4.83	4.16	4.51	3.91	4.79	5.63	4.05	6.47	6.90
Test coal dry basis	4.48	4.64	3.01	4.49	3.39	4.22	3.43	4.48	5.22	3.69	6.14	6.69
Nitrogen (%)												
HTWG specification	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Test coal as received	1.44	1.33	1.97	1.37	1.32	1.69	1.42	1.36	1.52	1.73	1.64	1.58
Test coal dry basis	1.52	1.40	2.09	1.43	1.47	1.76	1.52	1.43	1.61	1.80	1.76	1.63
Oxygen (%)												
HTWG specification	8.57	8.57	8.57	8.57	8.57	8.57	8.57	8.57	8.57	8.57	8.57	8.57
Test coal as received	13.58	18.52	15.87	20.93	18.87	15.87	19.32	17.04	14.08	15.01	13.31	11.21
Test coal dry basis	9.40	14.66	11.49	17.78	10.50	12.86	14.34	13.14	9.27	11.48	7.77	8.60
Sulfur (%)												
HTWG specification	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Test coal as received	1.09	0.80	0.91	0.93	0.77	0.84	0.94	0.86	0.85	0.81	0.72	0.83
Test coal dry basis	1.14	0.84	0.96	0.86	0.86	0.88	1.00	0.90	0.91	0.94	0.77	0.86
Ash (%)												
HTWG specification	11.70	11.70	11.70	11.70	11.70	11.70	11.70	11.70	11.70	11.70	11.70	11.70
Test coal as received	6.12	5.62	6.50	5.59	5.62	5.49	7.07	5.34	6.21	5.60	6.32	5.76
Test coal dry basis	6.43	5.89	6.88	5.83	6.26	5.73	7.56	5.58	6.63	5.83	6.76	5.97
Volatile Matter (%)												
HTWG specification	36.20	36.20	36.20	36.20	36.20	36.20	36.20	36.20	36.20	36.20	36.20	36.20
Test coal as received	36.87	41.57	36.24	40.18	34.10	38.43	37.14	38.94	36.46	38.11	37.00	39.53
Test coal dry basis	38.77	43.54	38.36	41.92	37.98	40.08	39.71	40.79	42.09	39.78	39.63	40.93

Test Number	1	1	2	2	3	3	4	4	5	5	6	6
Generator Number	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**3**
Fixed Carbon (%)												
HTWG specification	47.10	47.10	47.10	47.10	47.10	47.10	47.10	47.10	47.10	47.10	47.10	47.10
Test coal as received	52.12	48.29	51.75	50.08	50.05	51.96	49.32	51.20	48.09	52.22	50.06	51.30
Test coal dry basis	54.80	50.57	54.76	52.25	55.75	54.10	52.73	53.63	51.29	54.45	53.61	53.11
Heating Value (Btu/lb)												
HTWG specification	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
Test coal as received	13,306	13,231	13,223	13,445	12,310	13,723	12,798	13,603	12,791	13,489	12,710	13,334
Test coal dry basis	13,990	13,857	13,994	14,028	13,714	14,313	13,684	14,251	13,643	14,055	13,611	13,814
Ash Softening Temperature (°F)												
HTWG specification	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Test coal	>2750	>2750	>2750	>2750	>2750	>2750	>2750	>2750	>2750	>2750	>2750	>2750
Coal Size (% Less than 1/4 in.)												
HTWG specification	30	30	30	30	30	30	30	30	30	30	30	30
Test coal	18.85	12.70	32.28	15.16	34.86	5.61	34.04	8.45	32.75	7.70	35.47	6.94

Another indication of less than optimum combustion conditions is the level of excess air in the flue gas. Increased amounts of excess air in the combustion chamber tend to carry coal and ash particles through the HTWG, increasing the particulate load on air pollution control (APC) devices. Table 5 shows the generator excess air levels and indicates the amount of air infiltration between the HTWG and the exhaust stack. The generator excess air levels averaged about 88.4 percent (9 percent O_2) compared to the optimum combustion conditions of 56 percent excess air (7.5 percent O_2) listed in the generator operating manual. The difference between these numbers would not appear to be significant because at lower loads more excess air is needed to fully burn the fuel. However, experience has shown, even old units can achieve as low as 30 percent excess air (5 percent O_2) when tuned up. Some new spreader stokers have even been designed at 20 percent excess air (3.6 percent O_2) under optimal conditions.

Electrostatic precipitator operation

USAEHA personnel noted that the ESP had a number of warped collection plates and broken discharge electrodes. Conventional weighted wire ESPs typically have passage width tolerances of plus or minus 0.5 in. Warped plates can easily exceed these tolerances and cause increased sparking at the points of close collection plate/ discharge electrode spacing, which results in substantially reduced secondary voltages in the field. This condition has a very adverse impact on the fly ash collection

Table 5. Excess air and infiltration level.

Test No.	Generator Number	O_2 in Generator Exhaust (%)	Generator Exhaust Excess Air (%)	O_2 Exhaust Stack (%)	Exhaust Stack Excess Air (%)
1	2 3	10.2 8.4	95.7 67.4	12.0	135.5
2	2 3	10.0 10.1	92.1 93.4	13.2	172.4
3	2 3	7.5 9.2	56.1 78.9	11.1	113.8
4	2 3	9.2 10.2	78.9 95.7	14.0	204.2
5	2 3	10.7 11.1	105.4 113.8	15.0	256.1
6	2 3	10.8 9.0	107.4 75.9	14.1	208.7

efficiency. Broken discharge wires cause the same problem as they get bounced around by the flue gas flowing through the ESP.

The warped collection plates were most likely caused by high temperatures in the ESP resulting from hopper fires. Hopper fires occur when the ash has a high combustible content and there is significant air infiltration in the hopper area.

Broken discharge wires are caused by corrosion fatigue resulting from frequent operation below the flue gas acid dew point. Figure 4 shows the relationship between sulfur in coal and acid dew point. For test conditions of about 1 percent sulfur coal and 5 percent moisture flue gas, the acid dew point is 287 °F (°F = [°C × 1.8] + 32). The incoming temperature should be about 90 °F above the acid dew point to prevent

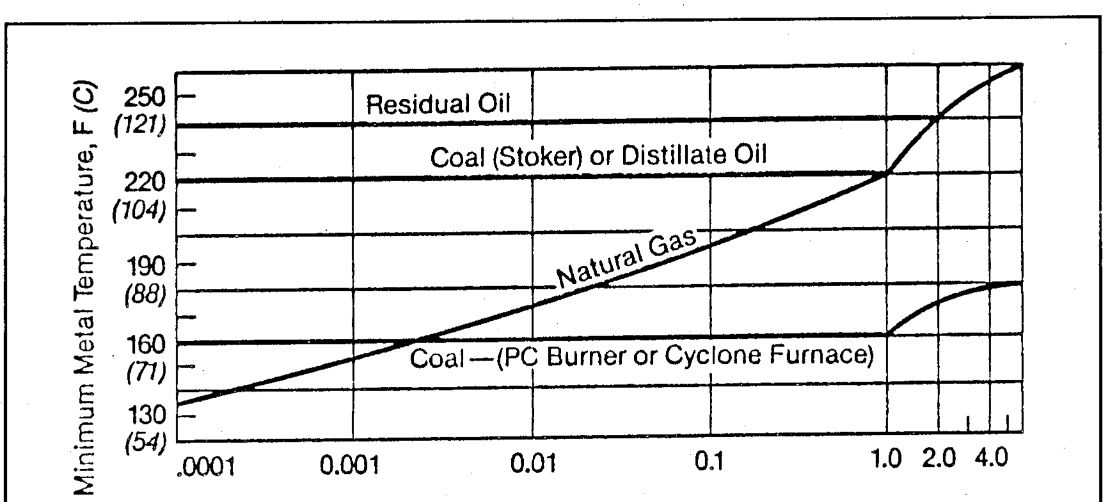

Figure 4. Relationship between sulfur in coal and acid dew point.

corrosion throughout the ESP. The ESP's walls will be much cooler than the center of the gas stream so the inlet gas temperature should be about 377 ^{O}F.

Table 6 shows temperatures at several locations in the ESP. The inlet and outlet temperatures are well below the acceptable level to prevent corrosion. The low hopper temperatures show substantial air infiltration that could lead to hopper fires.

Equipment Inspections

Inspection included visual inspection of coal storage and handling system, smoke bomb testing of all HTWG settings, and visual inspection of stokers, furnace area, fans, ducting, multicyclone collectors, and ESP. Only HTWGs no. 2 and 3 were inspected in detail to reduce project costs.

Coal storage and handling system

The coal storage and handling system is important to the combustion process for several reasons. Obviously, if the HTWG does not receive fuel, it has nothing to burn. Not quite so obvious is the coal storage and handling system's effect on the quality of coal sent to the HTWG. The most important quality parameter affected is coal size. Coal size may be altered by two basic actions; degradation and segregation. Both of these actions were occurring in the DCSC system. Degradation is the breakdown of coal to smaller sizes and segregation is the separation of coal into areas of small and large sizes.

Figure 5 shows a schematic representation of the DCSC coal storage and handling system. Overall, the coal-handling equipment appeared to be in good working order.

Table 6. ESP temperatures.

ESP No.	ESP Inlet Temp (F)	ESP Outlet Temp (F)	ASH Hop. No.1 Temp (F)	ASH Hop. No.2 Temp (F)
ESP No. 1 (1 ESP on-line) range Average	348-370 360	338-361 349	227-254 242	212-255 240
ESP No. 1 (2 ESPs on-line) range Average	309-357 327	285-341 307	208-255 228	172-228 192
ESP No. 2 (2 ESPs on-line) range Average	310-356 327	274-335 307	200-263 237	224-256 227

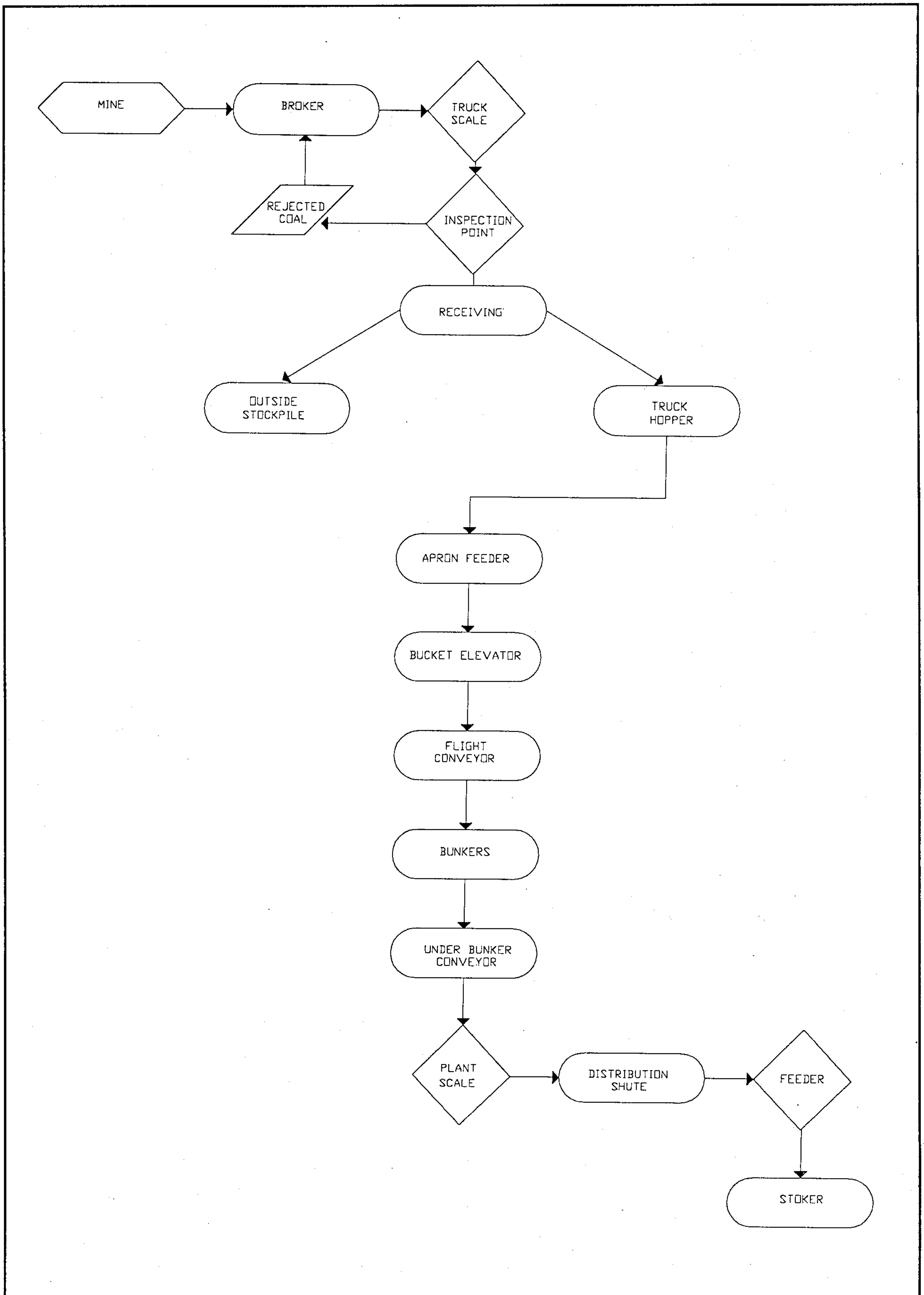

Figure 5. Schematic of DCSC coal storage and handling system.

Coal is normally delivered to the central heating plant by semi-trucks equipped with hydraulic dump beds for unloading. Coal is normally dumped near the outside stockpile, where DCSC personnel use a front end loader to shape and compact the stockpile.

This procedure is not good practice for bituminous stoker coal for several reasons. Piling the coal creates fines by agitation and segregates the coals. As discussed earlier, fines do not burn well in spreader stokers. Segregation occurs because large pieces of coal tend roll to the outside and lower edges of the pile creating areas of small pieces and areas of big pieces. In other words, the coal sizes are not equally distributed in the pile. The coal size distribution delivered to the feeder hopper must meet the specifications required by the stoker.

Second, large piles (over 10 ft tall) tend to spontaneously combust because, as the coal in the middle of the pile oxidizes, the resulting heat cannot dissipate through the thick pile. The heat builds up until the coal begins to burn. DCSC personnel noted that occasional fires are not unusual.

From the outside stock pile, coal is transferred to the plant by a front end loader that dumps coal into a ground level truck hopper, transfers it to an apron feeder, a bucket elevator, and a flight conveyor that fills the overhead bunker. The system did not contain a magnetic separator or sizing screen. The primary problem with this part of the coal storage and handling system was the method of filling the overhead bunkers from the flight conveyor.

The DCSC standard operating procedure for filling the bunkers was to leave all the slide gates on the flight conveyor open. This procedure causes segregation to occur in the overhead bunker. Figure 6 shows a schematic representation of this segregation. The bunker area under the first slide gate was filled first, creating a cone shaped pile up to the slide gate. With the first slide gate closed off with coal, coal would fill the area under the second slide gate. This procedure was continued until the bunker was filled.

This segregation causes slugs of fines and large coal to be sent to the HTWG feeders instead of the required homogenous size distribution. This will cause poor distribution of coal on the stoker grates, resulting in poor combustion and high particulate emissions. As discussed earlier, poor size distribution at the stoker feeders was identified during the USAEHA tests.

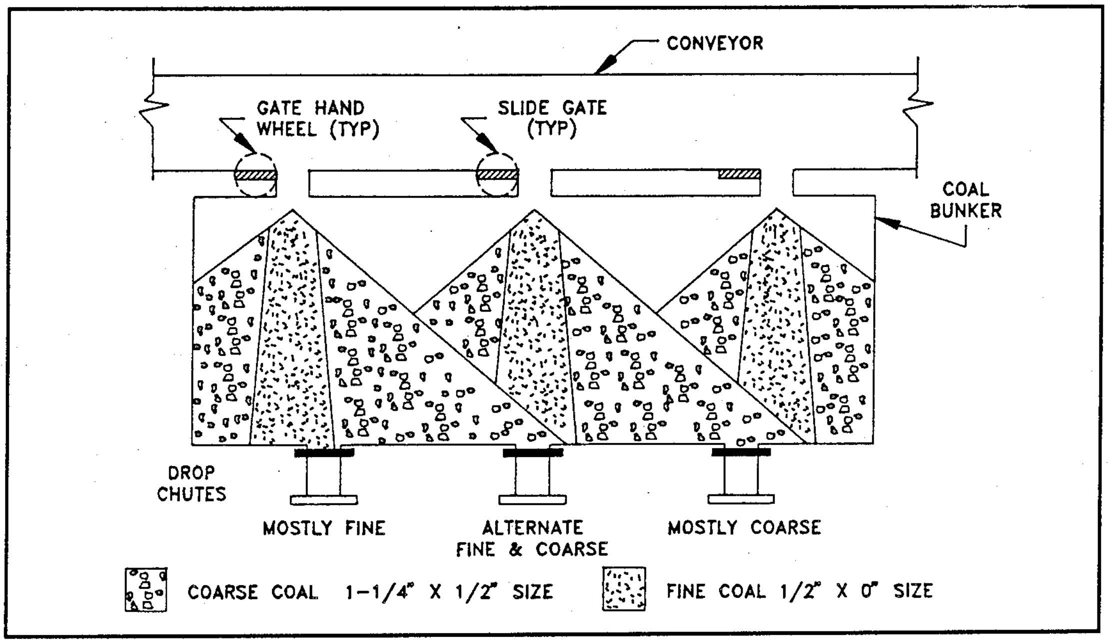

Figure 6. Schematic showing coal segregation.

Spreader stokers

A spreader stoker is an extremely versatile solid fuel burning apparatus. It will burn almost any solid material containing combustible matter. The proficiency with which the material is burned depends on a number of factors. The most fundamental factor in optimum spreader stoker firing is uniform fuel distribution over the entire effective grate area. Literally, this means an even proportion of coal sizes over the entire burning area.

The spreader stoker (Figure 7) consists of two basic components: the grate surface (Figure 8) and a coal feeder (Figure 9). The grate surface is a perforated table on which the fuel is distributed and burned. The coal feeder (a unit may contain one or more depending on unit size) controls the coal flow rate and its distribution over the grate surface.

These two components are linked together and to the rest of the combustion system through a combustion controls system. The control system can approximate the amount of coal that is fed into the furnace through the feeders and can proportion the amount of combustion air to the amount of coal. Unfortunately, the controls cannot determine or adjust coal distribution over the grate area. Adjusting the stoker for coal quality variation is one of the plant operator's most important duties.

Another important component of spreader stokers is the overfire air system. Many spreader stoker designs combine the overfire air system with an ash reinjection

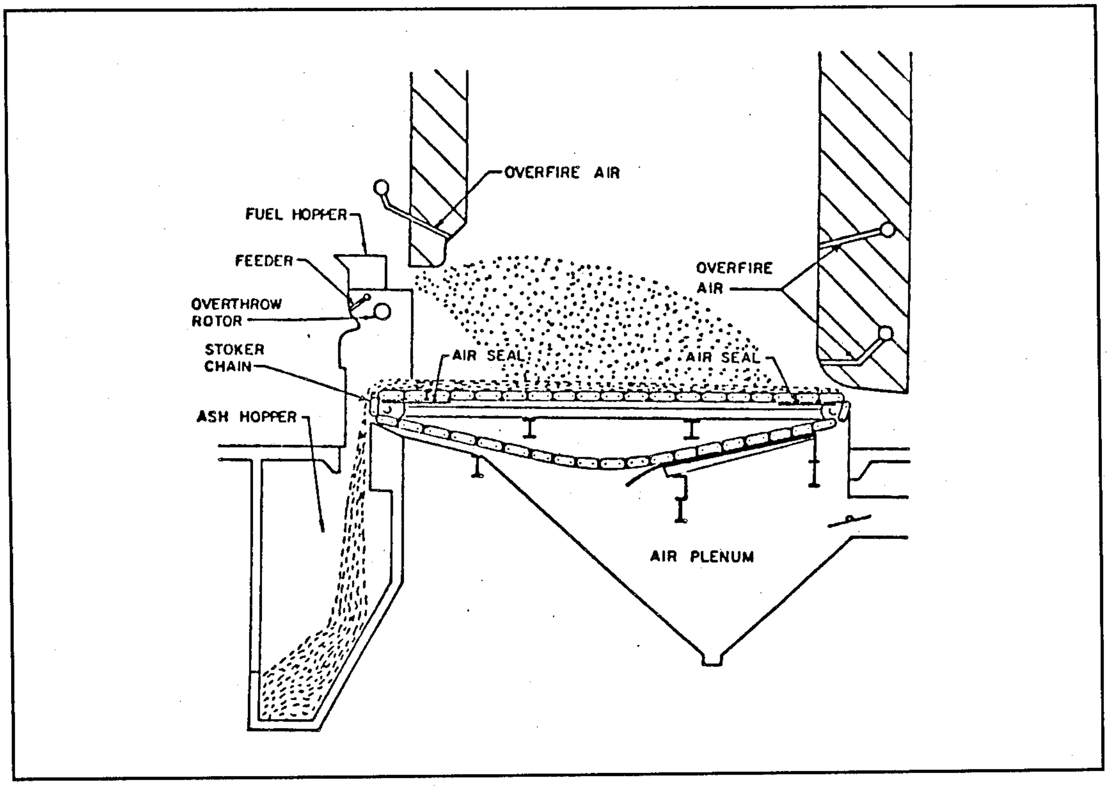

Figure 7. Spreader stoker.

system, as does the DCSC design. The ash reinjection system is designed to recycle some of the carbon particles that left the combustion chamber before they could be completely combusted.

Coal feeders. All three HTWGs have Model B Riley Spreader Stoker feeders. A careful inspection of HTWG no. 2 and 3 feeders showed that they were in excellent mechanical condition. No replacement of parts was necessary. However, observation of the lateral coal distribution on units no. 1 and 3 indicated that modification of some of the distributor paddle angles was needed to improve lateral coal distribution over the grate area. Figure 10 shows the existing paddle angles followed by the suggested arrangement. The improvement in coal distribution over the grate area will permit complete combustion of the fuel with less excess air.

Grate. Figures 11, 12, and 13 show important details for traveling grate operation. Of particular importance are: grate clips, air seals, and drive mechanism. The traveling grate on HTWG no. 2 was in excellent mechanical condition. The grate clips were sound and the skid shoes appeared almost new. The bearings on both the drive shaft and the idle shaft were in very good condition. The bearing inserts did not need replacement at that time. The shaft aligning collars on both shafts were secure and properly set for running clearance. The grate surface was square within the furnace.

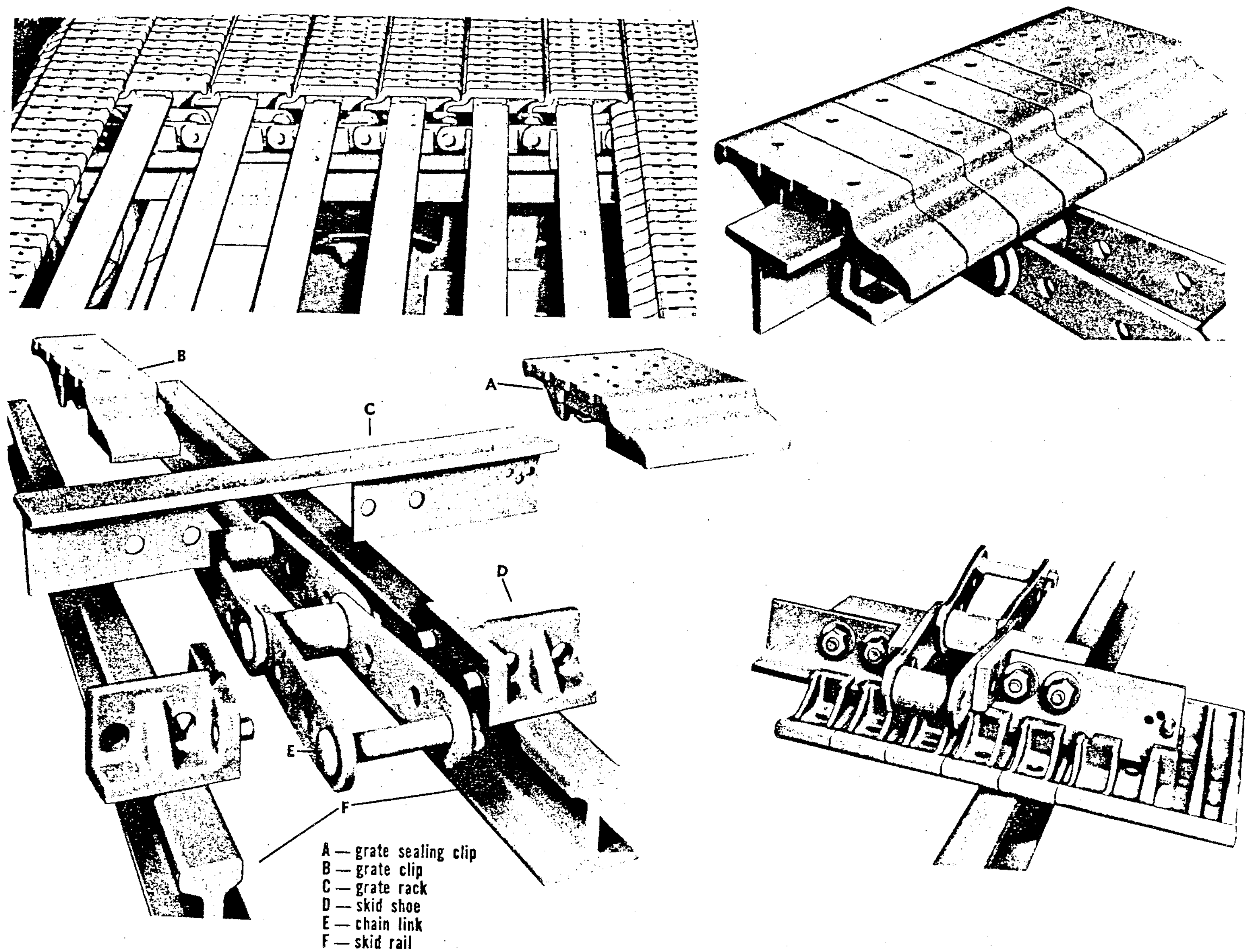

Figure 8. Grate surface.

However, there was insufficient grate clip growth clearance on the "TEE" bars to allow for free movement at maximum thermal expansion.

The castings forming the rear overgrate air seal showed some slight distress due to heat and wear but did not require replacement at the time of inspection.

The side air seals between the side sealing clips and the stationary seal castings were good, although the contact between these members could have been firmer. This is the result of the "TEE" bars bending upward slightly. Adjustment was not necessary for most of the bars, however.

The front air seals consisted of a stationary air seal under the top grate surface, intermediate seals hanging from the cross beam grating on the bottom grate surface and stationary castings forming the top of the wall separating the ash pit and the windbox. The return flight of the grate surface rides on this seal. All of these seals were in good condition.

1. Hopper
2. Gate
3. Pusher Box
4. Sealing Plate
5. Trajectory Plate
6. Trajectory Plate Adjusting Screw
7. Distributor Hubs
7A. Distributor Shaft
9. Distributor Housing Cover
10. Water Jacket
11. Water Jacket Cover
12. Sifting Tray
13. Front Cover
14. Stoker Arch
15. Deflector Tuyeres
16. Slag Resistant Refractory
17. Air Swept Cut-Off Plate
18. Front Dead Plate
19. Fire Door
20. Ash Pit Door
21. Rocker Shaft
22. Side Deflector Plate
23. Feeder Air Damper
24. Tile Support Bracket
25. Dead Plate Extension

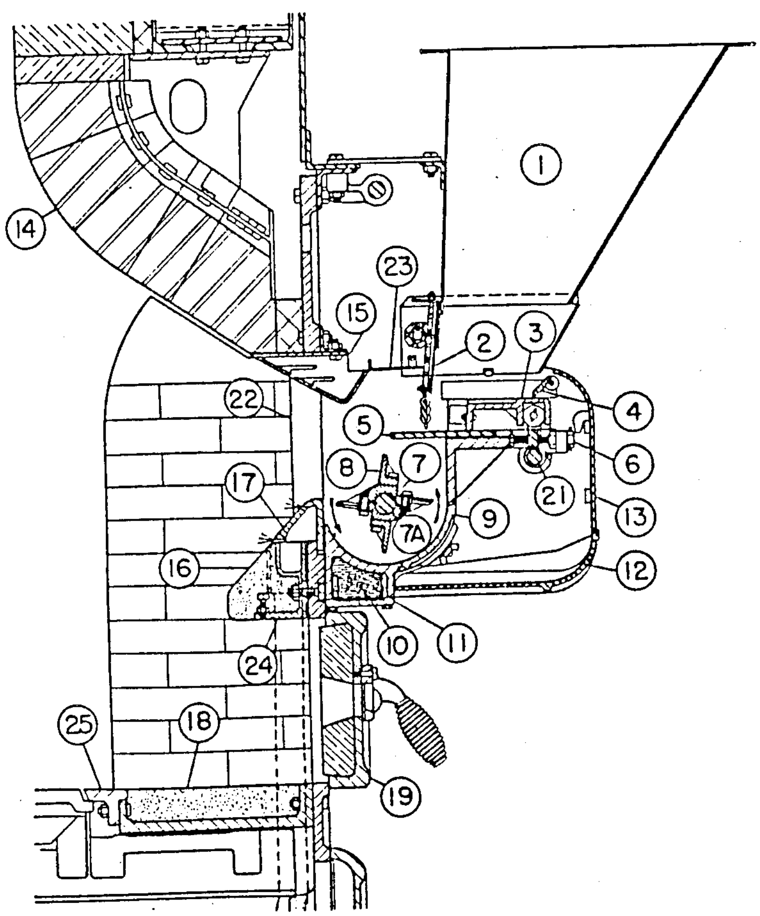

Figure 9. Coal feeder.

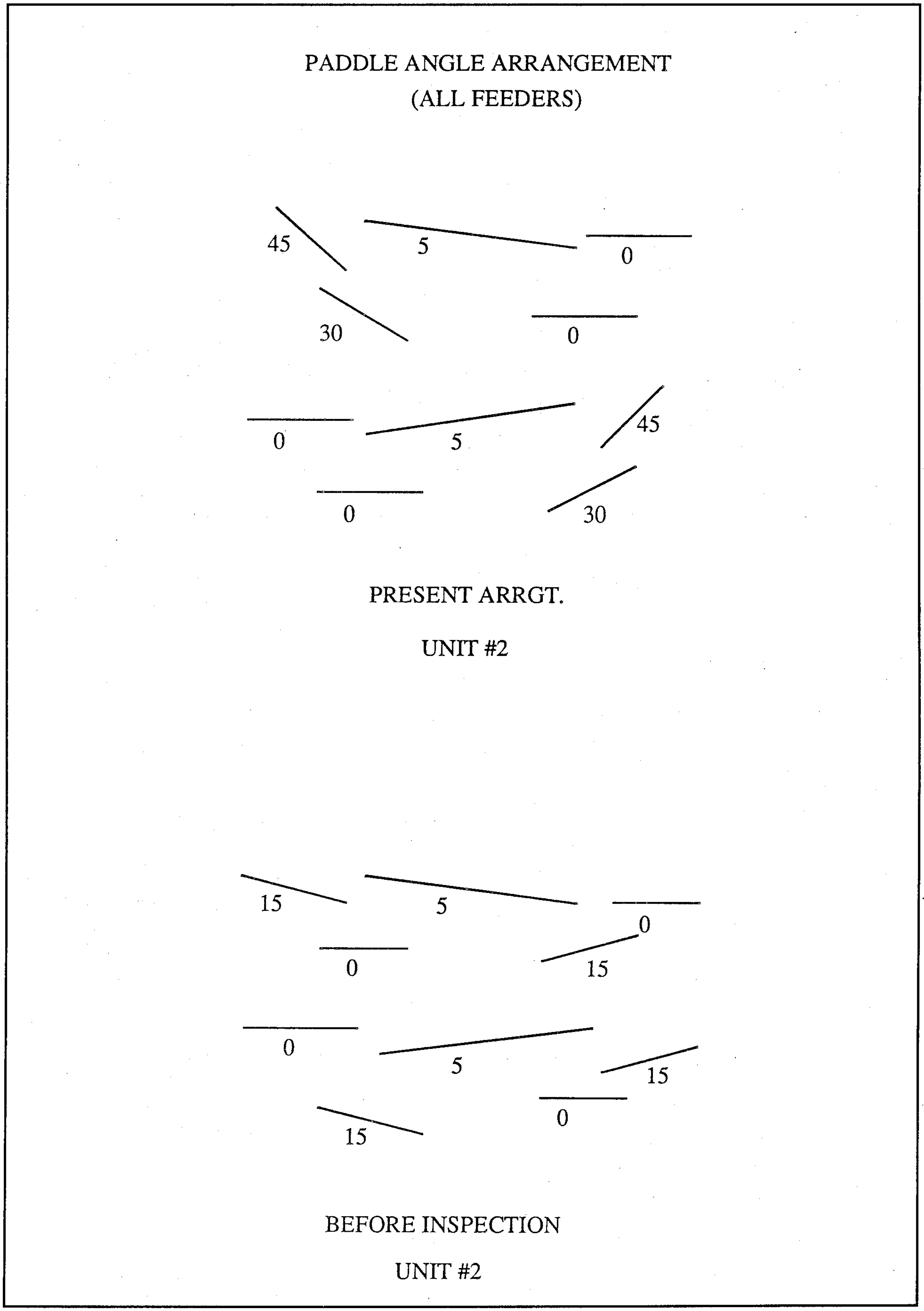

Figure 10. Paddle angle arrangements.

The grate clips on HTWG no. 3 showed definite overheating distress. The clips were humped and beginning to bind on the "TEE" bars (grate racks). To alleviate this, one 1-in. grate clip was removed from each rack (1 in. = 25.4 mm). The grate clip growth was undoubtedly due to operating with too thin an ash bed on the grate surface or running "clinkers" (inadequate excess air). If there is any further deterioration due to overheating, this grate surface will have to be replaced within 1 year. The rear overgrate air seal castings on this unit were similar to those on HTWG no. 2. The castings were wearing and subject to heat deterioration, but were still sound.

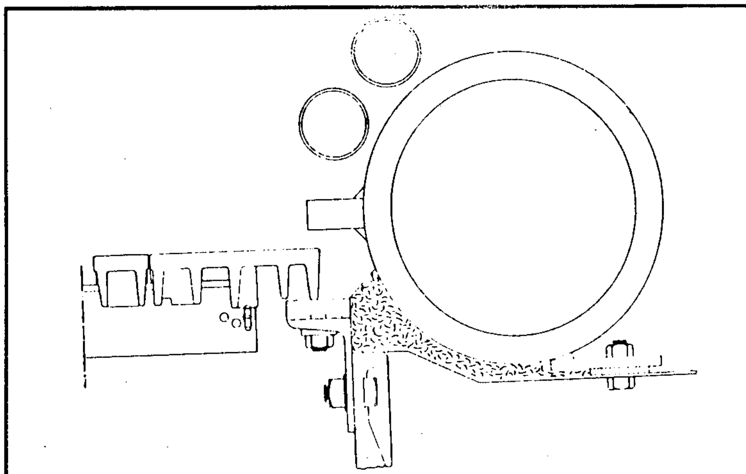

Figure 11. Travel grate details—sealing clips.

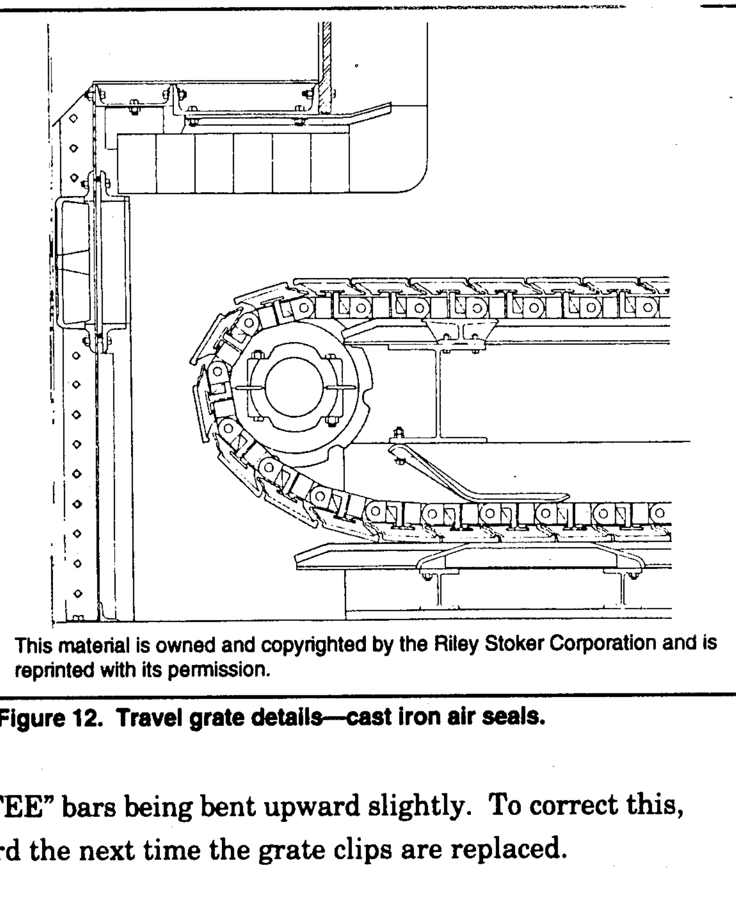

Figure 12. Travel grate details—cast iron air seals.

The side air seals were adequate and the stationary castings were in excellent condition. The sealing clips were in very good condition. However, the clips did not make firm contact with the stationary castings due to the "TEE" bars being bent upward slightly. To correct this, the bars could be bent downward the next time the grate clips are replaced.

The front air seals were in good condition. There are no broken or missing castings and contact between moving and stationary members was correct.

The hydraulic grate drives on all three units were in excellent mechanical condition. The oil flow control valve on each of the drives has a number of flow control ranges. When in the upper ranges the capacity of the valve exceeds the capacity of the

hydraulic pump. In this condition the drive will not run faster; it will simply lose pressure on the gauge. The three- valve range settings on all three units were reset so each grate would travel at the same speed when the dial settings are the same. For example, when the dial is set on no. 3, each grate is moving 3.6 to 3.7 ft per hour. The operator need only concern himself with the dial setting to control the grate's speed. When the dial is set at 10 (maximum), the grate will travel approximately 14 ft per hour.

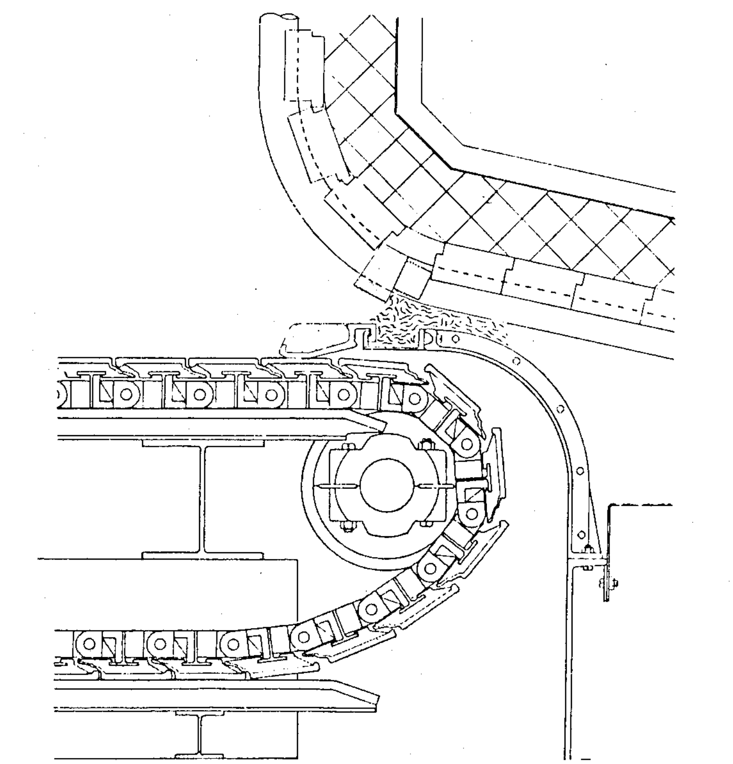

Figure 13. Travel grate details—refractory-filled air seals.

Overfire air/ash reinjection. The main purpose of overfire air is to create turbulent mixing of the combustion gases and carbon particles to improve combustion. The additional oxygen in the overfire air also improves combustion. Turbulence keeps particles in the furnace area longer where the temperature is the highest. Overfire air helps prevent overheating of tubes in the furnace area by keeping the flames from impinging on the tubes. Because overfire air can reduce the amount of unburned carbon exiting the furnace, smoking can also be reduced, which in turn reduces particulate emissions.

The overfire air systems for all three units are identical. Figure 14 schematically represents the overfire air system. Each has a single fan that discharges into two headers. A front header serves the air-swept cut-off plates in each of the three feeders. A rear header serves both the one row of overfire air nozzles and the three cinder reinjection nozzles returning fly-ash from the HTWG last pass hopper to the furnace. The fan produces a maximum of 25 in. static pressure. For maximum effectiveness, the rear overfire air nozzles should have at least 25 in. of static pressure for this furnace design. The ash reinjection nozzles can use about 10 in. of static pressure. Since both are fed from the same header, either one or both, must be compromised. This system should be redesigned to take advantage of newer and more effective designs.

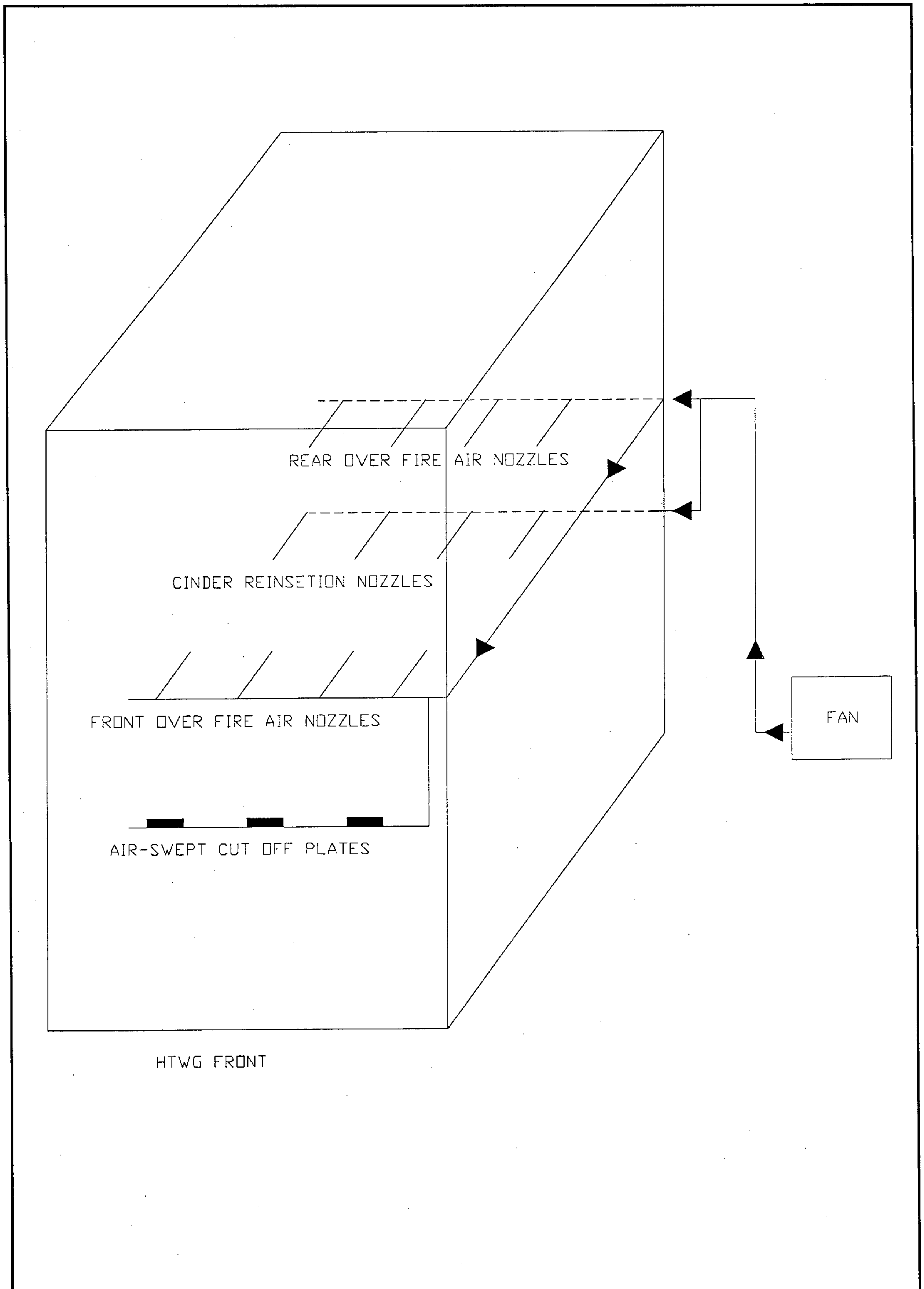

Figure 14. Overfire air system schematic.

On HTWG no. 2, one of the overfire air lines passing through the hopper was defective. The 2-1/2 in. pipe was broken at a pipe flange and was separated by about 2 in. Because of this leak, about 50 percent of the air supplied by the fan was escaping into the last pass hopper.

On HTWG no. 3, the three cinder reinjection lines and nozzles were in good condition; however, the rear row of overfire air nozzles needed repair. One nozzle had excessive clearance where the nozzle was attached to its supply tube. Plant personnel corrected this by filling the area around the nozzle with high temperature refractory up to the waterwall tubes. A second nozzle was missing entirely, which plant personnel replaced. A third nozzle was in place but not attached to its supporting tube. It was also repaired by plant personnel.

Combustion air fans

The FD fans on all three units are double inlet units with an inlet vane damper at each inlet. These dampers close metal-to-metal but are typical of inlet vane dampers. The damper linkages operate smoothly.

The induced draft fans are also double inlet fans. Each inlet has a multileave damper, two leaves per damper. These dampers are adjusted to remain open approximately 1 in. around each blade when the positioner is in the closed position. This arrangement provides too much leakage during light load operation, which makes it difficult to operate efficiently at low loads. The induced draft fan dampers on all three HTWGs should be realigned to close completely. In their current settings, at least 15 percent gas leakage can be expected with these dampers 100 percent closed.

Furnace refractory

On HTWG no. 2, all the refractory on the front wall was in excellent condition. DCSC personnel had recently replaced the refractory around the feeders. The feeder openings had a proper flare and will not interfere with coal distribution. The slope of the refractory across the bottom of the feeder openings was good. The air sweep holes in the cutoff plates were open. All the other refractory in the front, side, and roof areas was tight. The bridgewall refractory and the one refractory baffle separating the first and second passes of the HTHW heater were in good condition.

Similar to Unit no. 2, the front wall refractory in the unit was in excellent condition. The refractory around the feeders was quite new and properly installed in regard to slope and flare to prevent coal impingement. A few of the holes in the air swept cutoff plates required cleaning to assure that coal will not lay on the refractory slopes and

eventually interfere with coal distribution. Minor refractory patching was required around the rear overfire air nozzles. Otherwise the rest of the refractory in the front, side, and roof areas was tight. The bridgewall and the one refractory baffle in the rear pass were in excellent condition.

HTWG pressure parts

According to DCSC personnel, HTWG no. 2 had recently undergone a retubing. As expected, the tubes throughout this unit were in excellent condition at least on the fireside. A few of the access plugs in the lower rear header in the hopper were weeping. This is normal condensation because the HTWG is cold and the plugs are exposed to the hot gases in the second pass of the heater.

HTWG no. 3 had three tubes in the last pass that showed distress from overheating. Two of the tubes were at the bottom of the bank. DCSC personnel said that these had been plugged off. The third tube was two rows above the left distressed tube. It had sagged and rested on the tubes below it. This was pointed out to plant staff with the suggestion that it too be plugged if it were not already so. Inadequate water treatment is most likely the cause of this tube damage.

HTWG casings

HTWG no. 2 and 3 were pressurized with the FD fan and smoke-bomb tested for visible leakage of the HTWG casings. Figure 15 shows the location of the leaks. Access doors on both sides of the HTWG leaked excessively between frame and HTWG casing. Casing around side wall headers on both sides of HTWG leaked through 1/4 in. diameter holes in casing plates and through gaps between casing plates. On HTWG no. 3, the welds on lower plate of the right side header casing had broken loose, creating a large gap through which an excessive amount of leakage was evident. This casing plate should be welded back into place. Ash pit doors on both sides of the HTWG leaked excessively between door and HTWG casing. Observation doors and deslagging doors on both sides of the HTWG leaked between frame and casing. There was leakage through two drain holes in casings around the top and bottom rear headers.

Multicyclone dust collectors

Each HTWG had a multicyclone fly-ash or dust collector similar to the one shown in Figure 16. Under optimum operating conditions, these collectors can remove about 95 percent of fly-ash particles greater than 10 microns in diameter. The collection efficiency depends highly on the vertical vortex created by the centrifugal motion of the dirty gas as it enters the collecting tube through the inlet vanes (Figure 17).

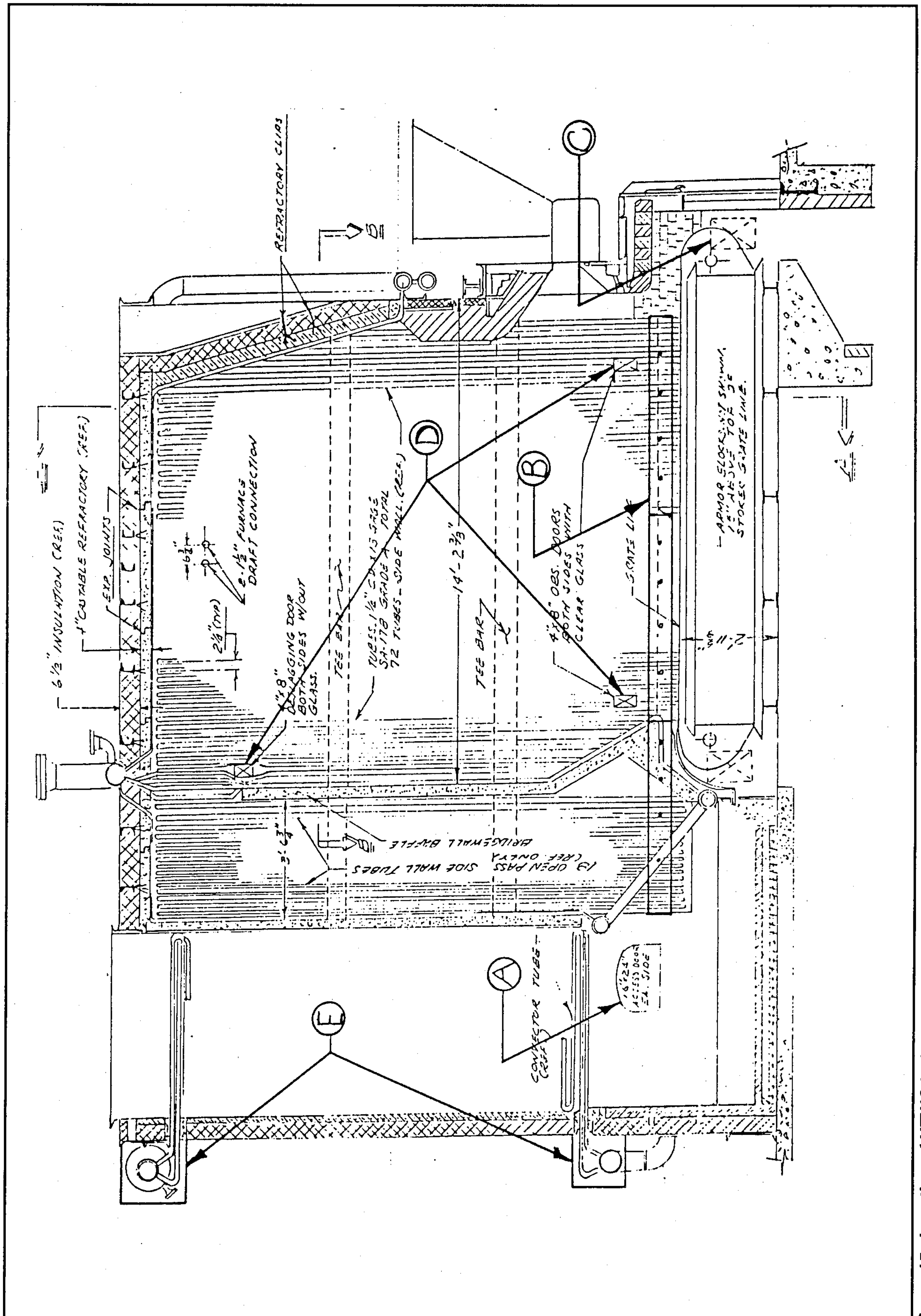

Figure 15. Location of HTWG leaks.

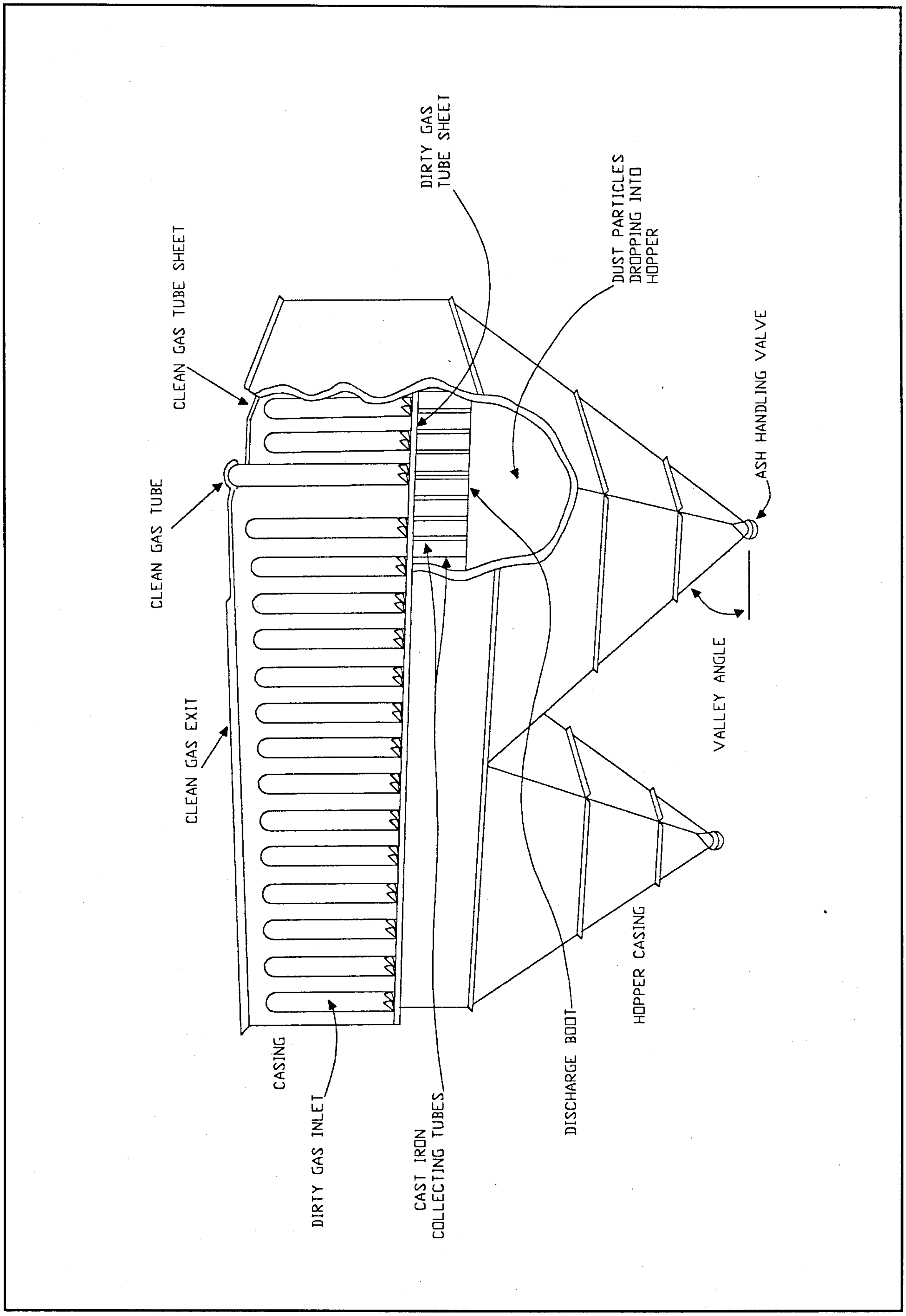

Figure 16. Mechanical dust collector components.

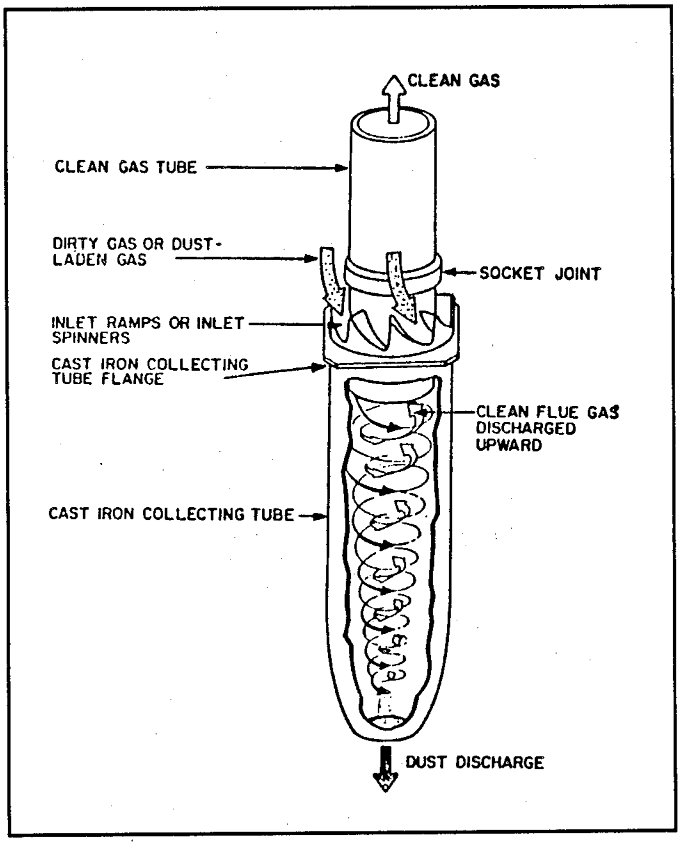

Figure 17. Single cyclone.

Each HTWG was equipped with a split mechanical dust collector. There were 25 multicyclones in each of the two sections. To maintain collector efficiency at light loads, there was a five-bladed damper ahead of one section of the collector. The damper was adjusted to maintain proper pressure drop across the collector. The dampers on each unit were frozen in the open position. (The heat of the flue gas had caused the grease in the damper bearings to carbonize.) Penetrating oil was injected into the bearings to free them. The damper shaft was also realigned. During preliminary testing, the pressure drop through the collector increased by about 1/2 in. of water or from 1 in. to 1-1/2 in. by closing this damper.

On both HTWG no. 2 and 3, the outer and inner tubes of the collector were in good condition. The turning vanes in both the outer tubes and inner tubes were in good condition. The collector on HTWG no. 2 had three cracked and dirty gas tubes and three worn discharge boots. The collector on HTWG no. 3 had one cracked and dirty gas tube and two loose discharge boots. Figure 18 shows the location of these defects. These relatively minor conditions can destroy the vertical vortex, essential to particle removal, and reduce collector efficiency.

Electrostatic precipitator

The common flue gas breeching connects the flow from all three HTWGs and directs the flow through the ESP. The flue gas is drawn through the ESP by a fan at the ESP outlet. The ESP was manufactured by Precipitator Pollution Control (Figure 19). The ESP has two modules, with one unit acting as a standby unit. Each module has two separately charged fields in series. The fields are a wire-and-plate type design. As flue gas passes through the fields, the wires impart a negative charge to the flue gas particles. A positive charge is maintained on the plates, which attracts the negatively-charged particles. The accumulated fly-ash particles are removed by a rapping mechanism at the top of the plates, and then fall into an ash hopper below

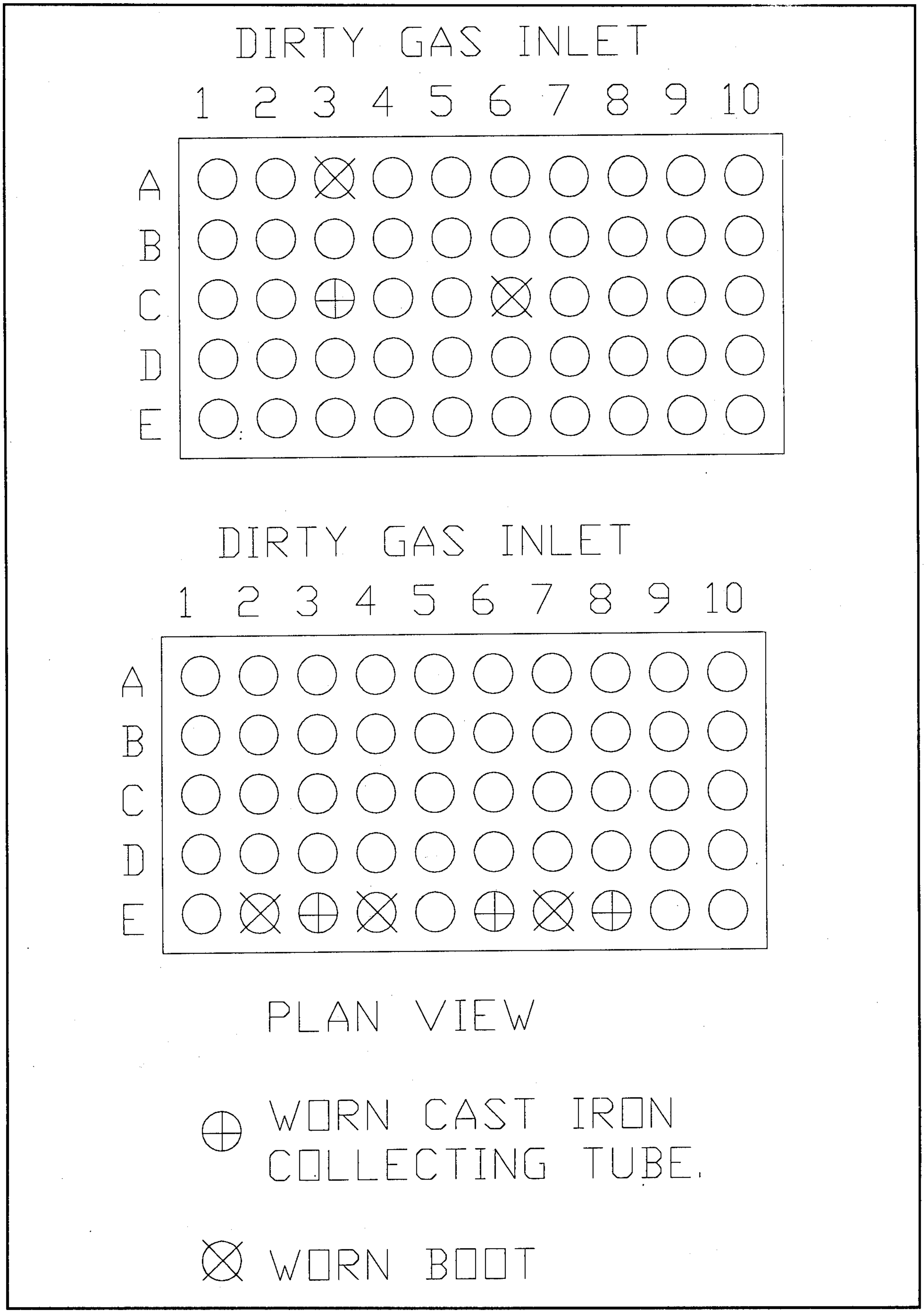

Figure 18. Mechanical collector inspection.

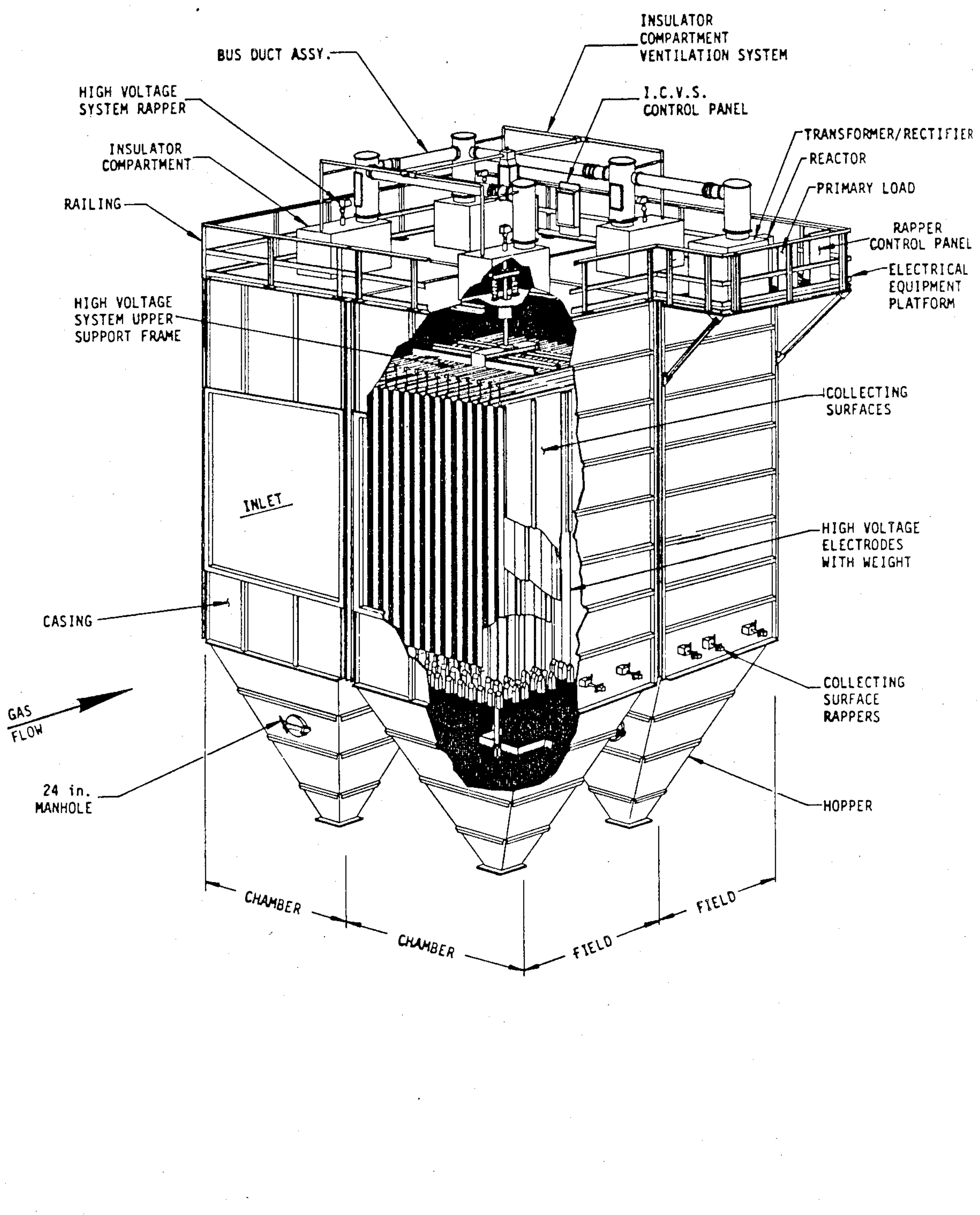

Figure 19. Electrostatic precipitator.

the plates. The ash is removed by the same ash handling system used for the HTWG bottom ash and multicyclone collector ash.

The ESP had recently undergone a thorough repair project and was in excellent physical condition. The repair project included the addition of plate straighteners to correct plate alignment problems probably caused by hopper fires.

A routine inspection of the ESP did not identify any signs of damaged equipment or improper plate-discharge electrode alignment. However, the ESP walls showed signs of internal corrosion. An operational inspection identified a faulty temperature measurement device at the ESP inlet. When compared to test instrumentation, the device showed a reading 40 to 50 °F higher. This may have lead operators to erroneously believe the inlet temperature was high enough to avoid the acid dew point. Operation inspection also identified faulty wiring in the ESP control panel. A broom had accidentally hit the side of the panel, tripping the ESP induced fan off.

A dew point temperature of approximately 288 °F was estimated using ultimate analysis of the coal burned during USAEHA stack tests. Note that this is the minimum temperature everywhere in the ESP. Typically, temperatures are only taken towards the middle of the gas stream and not at the walls or hopper areas, which will be at the lowest temperatures.

Ash handling system

Ash from coal-fired furnaces and emission control equipment can be removed by conveying the ashes in a pipeline either hydraulically or pneumatically. In a pneumatic conveying system, the ash is carried through the pipeline in an air stream. In a hydraulic conveying system, the ash is slurried and carried through the pipeline in water. DCSC uses a pneumatic ash conveying system similar to that shown in Figure 20, without the baghouse.

Current operating procedure was to open the ash valve on the bottom of a mechanical collector or ESP and allow the ash handling system to be in normal operation. The vacuum is on the ash handling system for a short amount of time; i.e., 2 minutes, and then the vacuum is turned off the ash handling system by using a vacuum breaker for 1 minute to allow the accumulated ash in the primary separator to drop into the ash silo. When the vacuum was not on the system, it was not customary to close the ash valve on the bottom of the mechanical collector or ESP. Since the hoppers of the mechanical collectors and ESPs are under negative pressure, ambient room air would

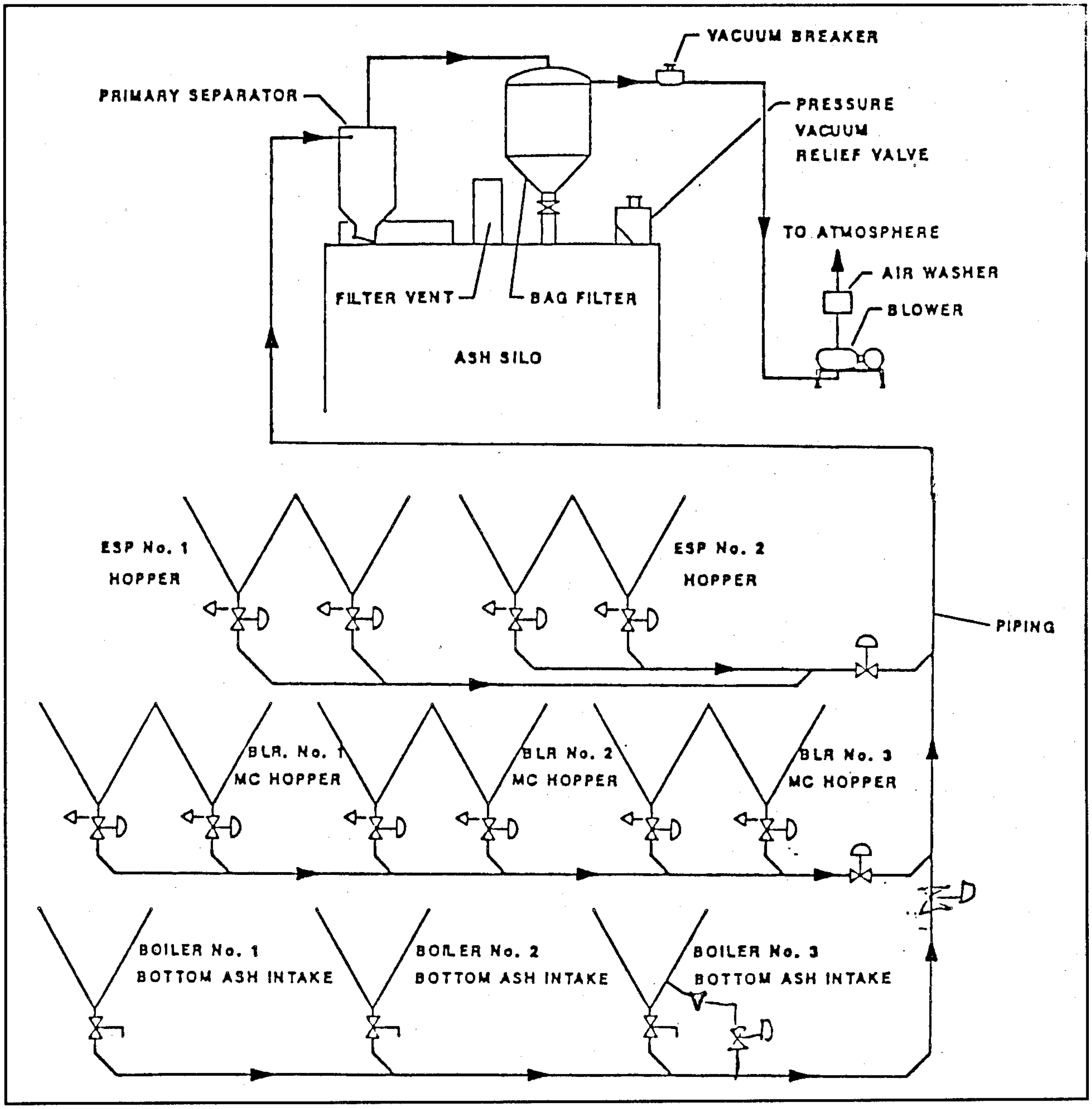

Figure 20. Pneumatic ash handling system.

flow in through the ash pipe and up through the valves into these negative pressure hoppers, carrying fly ash to the generator I.D. fan and contributing to erosion and air pollution at the ESP hoppers.

Another problem noted was in the ash/air separation component of the system. As the ash reaches the ash silo, it is removed from the conveying air through a one-stage (Primary) cyclone separator. With the advent of the Environmental Protection Agency (EPA) and passage of the Clean Air and Clean Water Acts, a final stage of separation or filtration of the conveying air was required to meet EPA guidelines for particulate emissions. This final stage could come in the form of a fabric filter or a venturi

scrubber. DCSC originally used an air washer to meet the final stage separation. The air washer stage was maintained in the system as a standby component to the final stage filtration component. However, the air washer only filtered coarse fly ash particles and allowed the fine particulate to pass through. In addition, the particulate that was filtered by the air washer became suspended solids in the effluent which was then discharged into a sewer, possibly causing a violation of the Clean Water Act.

The primary cyclone collector seal was also worn, causing ash particles to swirl around the lower areas of the cyclone, thus wearing a hole through the cyclone casing. Both the worn seal and the hole in the casing greatly reduced the collector's efficiency.

4 Short Term Improvements

The following chapter summarizes guidance on optimizing the performance of both combustion and air pollution control equipment based on the system review and inspection described in Chapter 3.

Coal Quality

Stoker-fired coal must meet a fairly rigid set of specifications to burn properly. Traveling grate spreader stokers like those at DCSC should be provided bituminous coal meeting the specifications shown in Table 7 and Figure 21. The most important specifications for stoker operation are *ash fusion temperature* and *size distribution.*

Ash fusion temperature provides an indication of the tendency of the ash in the coal to partially melt in the burning process. Most coals in the Ohio area have an ash fusion temperature lower than the flame temperature of the fuel. To avoid the possibility of the ash melting and fusing to form "clinkers," the fuel bed must burn out rapidly. This limits the time that the ash is exposed to the flame of the burning fuel and limits the temperature of the ash to below the fusion temperature.

To compensate for these problems, the operator must increase the amount of combustion air above normal to ensure that all the combustible material in the fuel bed burn out. This increase is undesirable because high air flows tend to carry over fly-ash into the multicyclone collectors and scrubber, thereby reducing the efficiency of those pollution control devices.

Table 7. Travelling grate spreader stoker specifications (bituminous coal).

Parameter	Specification
Proximate Analysis:	
Moisture (M)	15 - 20 %
Volatile Matter (VM)	30 - 40 %
Fixed Carbon (FC)	40 - 50 %
Ash	5 - 20 %
Heating Value:	10,500 - 14,000 Btu/lb
Free Swell Index:	7 - maximum
Hemispherical Temperature:	2,100 of minimum
Size Distribution:	1-1/4 by 1/4 in. (See graph for distribution)

The size distribution specification provides

the stoker with the proper coal sizes to obtain uniform distribution of coal across the width of the stoker. If the coal distribution over the grate area is not uniform, it will cause three problems:

1. Uneven coal feed between feeders
2. Uneven porosity in the fuel bed, which will cause an uneven proportion of combustion air to coal in different areas of the grate
3. A longer burnout time in areas of the fuel bed that have the larger coal sizes, further upsetting air to fuel ratio in areas of the fuel bed.

As with improper ash fusion temperature, the operator must increase the amount of combustion air above normal to assure burnout of all of the combustible material in the fuel bed.

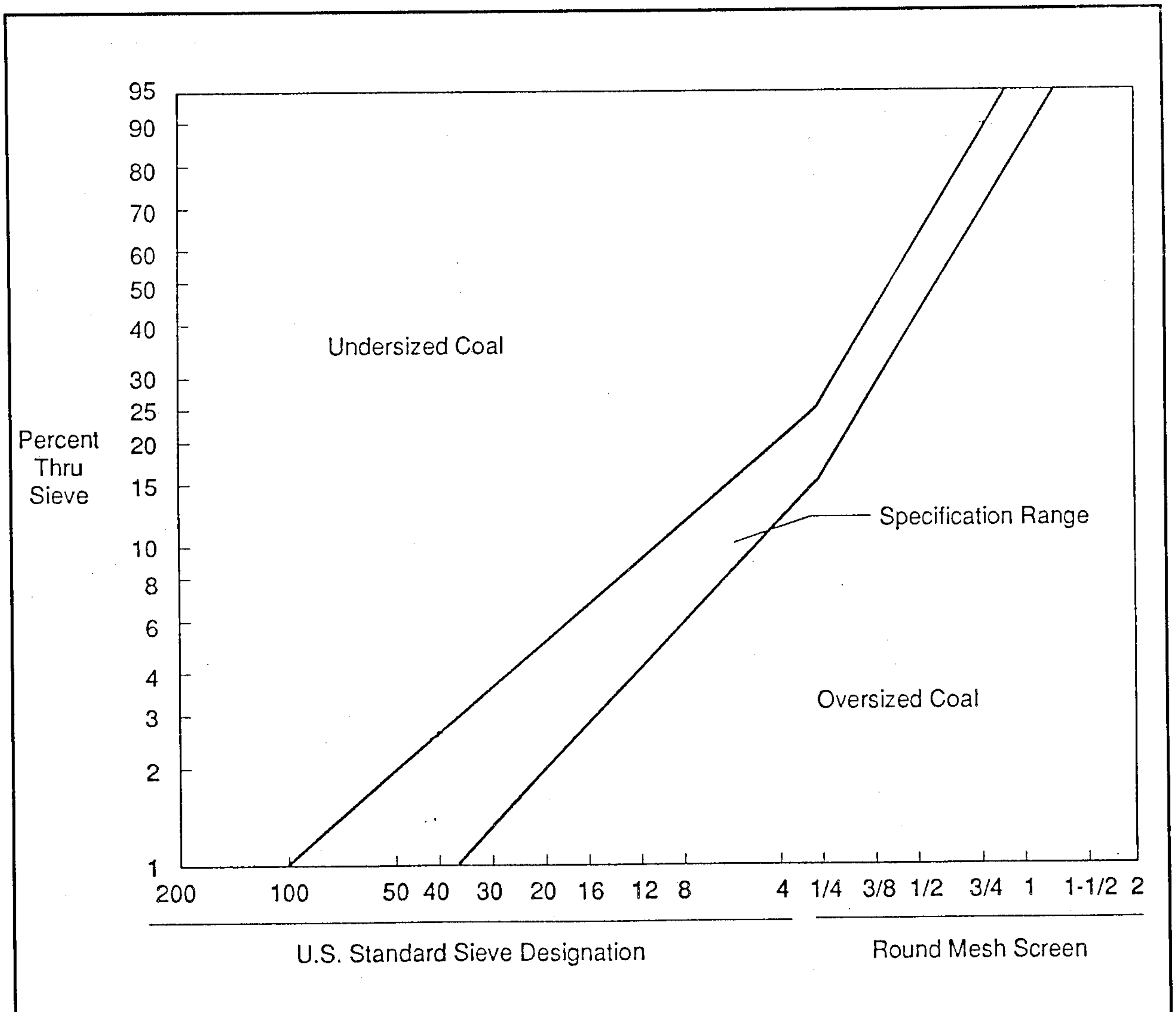

Figure 21. Travelling grate spreader stoker size specification for bituminous coal.

All coal shipments should be inspected and sampled according to Defense Fuel Supply Center (DFSC) guidelines. After a coal shipment has been received and found to be correct by matching delivery papers to the current contract, the coal should be inspected visually for the presence of foreign material such as slate, pyrites, trash, excessive moisture, dirt, etc. If the coal appears to contain excessive bigs or fines, a size analysis must be made. If the coal does not meet specifications, it should be rejected. Before the coal can be accepted and used, the inspector must collect a sample for chemical analysis as described in DFSC Manual 4185.1

Coal Storage

To prevent degradation of coal in outside storage piles, the piles should be kept to a maximum of 10 ft high. The coal may be compacted only if a rubber tired vehicle is used, because tracked vehicles will break the coal creating an undesirable amount of fines. Potential for spontaneous combustion can also be reduced by keeping foreign material such as rags and paper out of the pile and sealing the pile with chemical sealants or plastic. Thermocouples can be inserted into the pile to take the coals temperature to determine if there is a potential for fire.

Coal pile fires can be put out by inserting a pipe into the pile capable of delivering dry ice to the area on fire with the following procedure. Make a point on the end of the 12-ft length of 4-in. pipe. Seal the weld between the strips of pipe that make the point. On the plain end of the pipe, cut standard pipe threads and install a coupling with pipe plug. On the straight side of the pipe, near the point, drill twenty 1/2-in. random holes in 3 ft of pipe. Drive the point into the hot spot of the coal pile. Remove the pipe cap. Fill the pipe with dry ice (solid CO_2) and replace pipe cap. The heat will gasify the dry ice and the CO_2 gas will displace air through the 1/2-in. holes and extinguish the fire. Keep refilling pipe with dry ice as required. Monitor the internal CO_2 pressure and do not try refilling the 4-in. pipe with dry ice until zero psig is indicated on a monitoring pressure gage of the internal 4-in. pipe pressure. If sufficient dry ice is used, the hot spot will generally cool down to normal. Continue to monitor the thermocouple until the hot spot has cooled.

Carefully remove the hot coal from the pile and spread it thinly (2-in. deep) in a separate area from all other coal. Find some cool, fine-sized (1/4.x 0-in.) coal and cover the hot coal, then compact it to remove all air. Do not use water to cool the coal pile.

After the heat has been removed from the coal, move the fuel into a bunker which has a low coal level. Fire the poor quality (partly oxidized) coal through the stoker as soon as possible. Monitor the poor quality coal in the bunker so a fire does not develop in

the bunker. Everyone in the plant (plant supervisor, generator operator and assistant operator) should be notified that problem coal is in the bunker.

Plant personnel have also covered the long-term coal pile with plastic sheets, which is a great improvement because it:

1. Reduces the flow of air through the coal pile, which in turn reduces oxidation and coal pile, fires (spontaneous combustion)
2. Reduces rainwater from moving through the coal pile, which creates acidic runoff in storm sewers
3. Reduces the amount of very fine coal from running off with the rainwater to form suspended solids runoff into storm sewers
4. Reduces the loss of coal to wind picking up the fine coal and carrying it away from the coal pile, and also reduces fugitive particulate in the ambient air.

The coal should be handled as little as possible to avoid segregation and creation of fines. One way to do this is to use just-in-time (JIT) delivery instead of first-in, first-out. When coal is stockpiled and fired on a first-in, first-out basis, the coal being used is often a year or more old. A long-term coal pile that can be compacted and sealed can be established as an emergency pile. Coal deliveries should then be arranged so that coal can be delivered directly to the silo hoppers. This method allows the coal to be used before it has a chance to degrade and avoids costs of rotating and rebuilding coal storage piles.

JIT reduces the amount of labor and equipment cost to move the coal from the coal pile to the unloading hopper. JIT also minimizes the amount of surface water weight added to coal. Surface moisture added to the coal is evaporated in the furnace, exits the stack as a superheated steam loss, and actually decreases the efficiency of the generator. Up to 10 percent moisture (by weight) can attach itself to the surface of the coal. The efficiency loss for 10 percent moisture is about 1.2 percent. As discussed in the coal quality section, wet coal causes very poor distribution of fuel on the grates, which in turn increases excess air, thereby losing about another 2.50 percent efficiency. The two combined can add up to a loss of 3.7 percent efficiency.

Some disadvantages of JIT are: it requires plant personnel supervision to closely monitor weather, predicted coal usage, and amount of coal stored in overhead coal bunker and truck deliveries. Frozen coal in the truck is also a problem. An Ohio law requires that all open trucks must be covered with a tarp to reduce surface moisture and frozen coal. Frozen coal in a truck is usually created when wet coal is loaded in the truck after 1600 hours and remains in the truck all night in falling ambient

temperatures. At 0900 hours the next day, the perimeter coal is frozen together due to the surface moisture.

The estimated savings of these improvements are:

1. From efficiency improvement:

   (3.7%) × (10,600 tons/yr) × ($48.00/ton delivered coal cost) = $18,800/yr

2. Labor and equipment annual savings from moving coal from pile to the unloading hopper:

   $1.50/ton × 10,600 tons/yr = $15,900/yr.

Coal Handling System

Plant personnel have raised the height of the unloading hopper lip so the rainwater that runs across the ground does not enter the coal hopper. This has reduced the amount of surface moisture added to the coal.

Plant personnel have added a coal splitter under each coal drop gate in the flight conveyor on top of the overhead coal bunker in the plant, which has reduced segregation of coal in the bunker.

Past practice of allowing the bunker to be filled at one gate point under the flight conveyor at the top of the overhead bunker in the plant has been changed. Operators now fill the bunker from one gate for approximately 3 minutes, close the gate and go to the next gate, fill the second bunker for 3 minutes, and then go to a third gate. This procedure is repeated, from the first gate and in the same sequence for each HTWG. This greatly reduces segregation of coal in the coal bunker. The result of the original method of operation was shown in Figure 6. The result of the new method of operation is shown in Figure 22.

Spreader Stokers

As discussed in Chapter 3, the most fundamental factor in optimum spreader stoker firing is uniform fuel distribution over the entire effective grate area. This can only be accomplished by maintaining fuel quality and by attending to feeder and grate speed adjustments as variations in fuel quality occur.

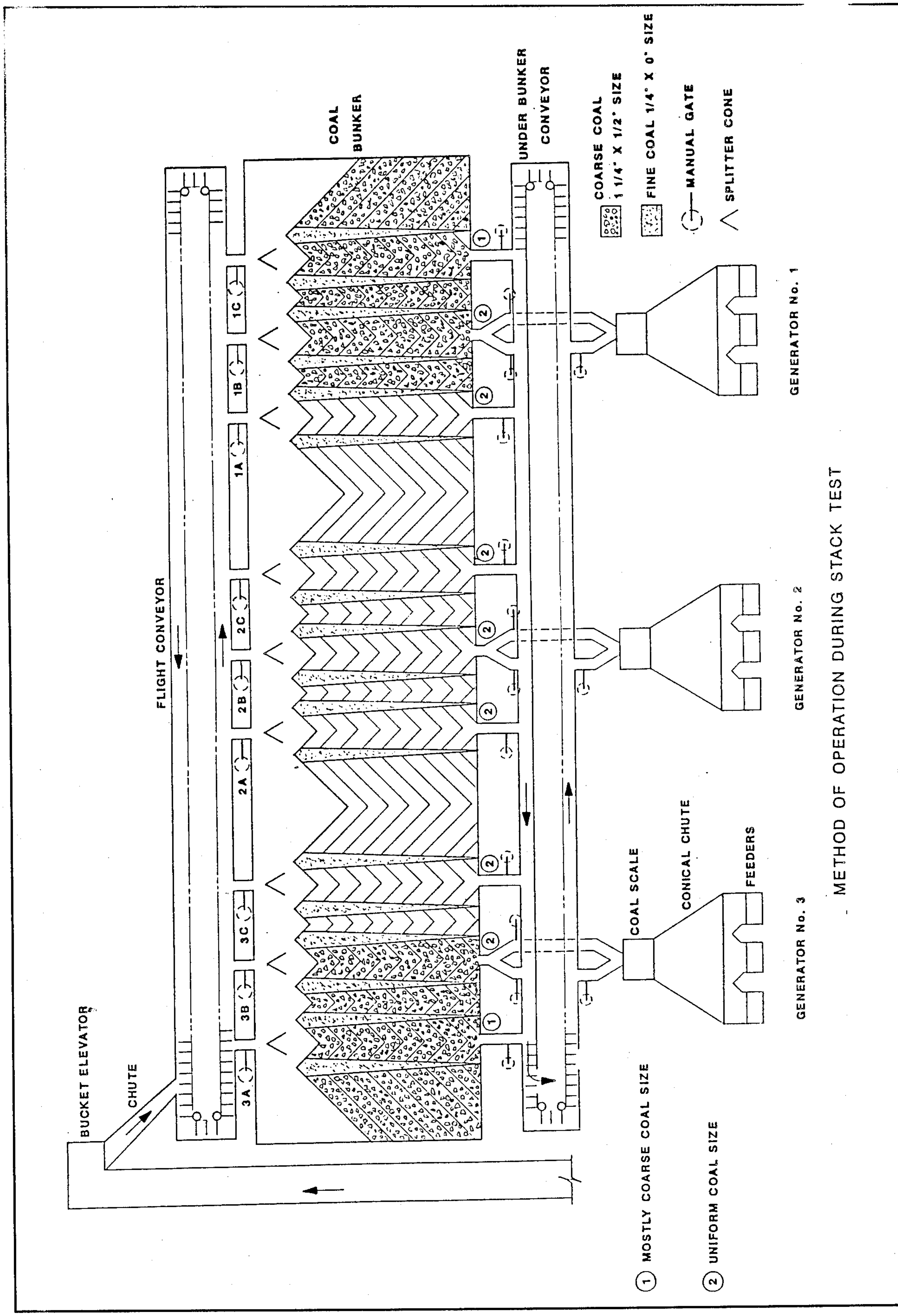

Figure 22. New coal handling system.

The stoker and auxiliary equipment should have a complete general inspection at least once a year. This should include inspection of the entire grate surface, looking for worn skid shoes and rails, burned grate clips, bent grate racks, worn chain links, grooved side seal ledge plates, and worn grate sealing clips. Drive shaft and idler shaft bearing wear should also be noted, along with condition of the sprockets. These sprockets can be reversed, if necessary, to obtain a new wearing surface.

Feeder adjustments

As stated earlier, the feeders have two functions: to control the amount of coal fed into the furnace, and to distribute this fuel uniformly over the entire grate area. Since there is more than one feeder per stoker, the operator is responsible to see that all feeders on one stoker are feeding an equal amount of coal to maintain uniform distribution over the grate area. This is best observed by estimating the ash depth on the grate surface just before it is discharged into the ash pit.

The ash depth must be uniform across the lateral width of the stoker (remember that the depth of ash represents hours of coal distribution into the furnace). If the ash depth is uneven, then the area of the grate with the most ash is getting more than an even proportion of coal. If the ash depth is uneven below the centerline of each feeder, then the feeder feed rates must be adjusted. This is accomplished by adjusting the fuel feed control mechanism that advances or retards the fuel feed of each feeder individually with respect to the combustion control positioner.

If the ash depth is uneven between the centerline of the feeders, the spaces between the feeders or the angle of the distributor paddles must be adjusted in the Riley feeders, or the rotor blades must be changed in the Detroit feeders. Without exception, this unevenness appears as too much ash along the centerline of the feeders and not enough ash between feeders. This imbalance in lateral (side to side) coal distribution is corrected by resetting the paddle angles on the Riley feeders or by replacing the rotor blades on the Detroit feeders. This is not an adjustment made by the plant operator during normal operation, but rather during maintenance periods.

Coal distribution from front to rear (longitudinally) is as important as lateral distribution. Distributing enough coal to the rear of the grate surface is a function of *trajectory plate* setting and *paddle* speed. With the trajectory plate adjusted into the furnace, the face of the paddle is nearly vertical to where the coal falls off the trajectory plate. To drive coal to the rear of the furnace with these settings, the paddles must be turning at relatively high speeds. This results in the coal following a flat trajectory.

With these conditions, coal is distributed along the length of the grate. The largest lumps have the greatest inertia and travel the farthest. Further, many of the lumps that hit the fuel bed around the rear third of the grate tend to ricochet off the rear wall of the furnace. And finally, the high paddle speeds result in a considerable amount of the lumps not falling in front of a paddle but being tipped by a paddle. These lumps will dribble off the feeder and land on the fuel bed at the discharge end of the grate. The total effect is one of poor longitudinal fuel distribution.

With the trajectory plate adjusted out of the furnace, the face of the paddle is looking upward when it impacts the lumps of coal. In this mode, the coal trajectory is high and coal will reach the rear of the furnace with a much lower paddle speed. When a lump of coal impacts the fuel bed it is traveling in a more vertical direction, which greatly reduces the tendency of the lumps to ricochet to the rear of the furnace. And finally, with the lower paddle speed, considerably fewer lumps are tipped by a paddle with substantially less coal dribbling off the feeders. This produces a much better longitudinal coal distribution.

Longitudinal coal distribution will vary with coal size or surface moisture. An increase in coal size will require a reduction in paddle speed to maintain distribution. Also, an increase in surface moisture will require an increase in paddle speed to maintain distribution.

There are observation doors on each side wall of the furnace just forward of the rear wall at the firing level. Longitudinal coal distribution is determined by observing the flame pattern through these doors. Longitudinal distribution is proper when one can look at least half way across the furnace along the rear wall at the level of the doors. When looking down toward the grate surface through these doors one sees only bright orange flame. If one sees only orange flame at the level of the door, there is too much coal being distributed along the rear of the furnace.

A second observation to determine longitudinal distribution is to note the undergrate temperatures. Proper longitudinal distribution will result in the lowest possible undergrate temperatures.

A third observation is to carefully watch the ash bed on the grate surface as it is being discharged into the ashpit. If there is excess coal being burned at the rear of the furnace, there may be a tendency of the ash to begin to fuse together on the bottom of the ash bed or directly on the grate metal surface. If excess coal is being burned toward the front of the furnace, the ash may begin to fuse together at the top of the ash bed. Either of these conditions would vary depending on the amount of combustion air

passing through the fuel bed, the size or oversize of the coal, and the ash fusion characteristics of the coal.

Based on these practices, the distributor blades on the coal feeders were adjusted for better coal distribution on the grate (Figure 10).

Grate speed adjustment

The grate surface is a perforated metal surface on which fuel is distributed and burned. This is the sole function of the grate surface. The reason that the grate travels from the rear to the front of the furnace is only to carry and discharge accumulating ash into the ashpit. This is correctly called "continuous ash discharge." Considering this, *the speed of the grate should be determined entirely by the ash depth.* The grate speed should be adjusted to maintain an absolute minimum of 3 in. of ash on the discharge end of the grate. For best stoker performance, the ash bed should be 5 to 7 in. Accordingly, grate speed will be increased when firing rate is increased or if a coal with higher ash content is burned. The rule is very simple—*maintain approximately 6 in. of ash on the discharge end of the grate surface at all times* by adjusting the grate speed. Warning: this refers to the *ash bed*, not the fuel bed.

The insufficient grate clip clearance on the "TEE" bars was corrected by removing one of the two 1-in. clips on each "TEE" bar, providing approximately 1-1/2 in. expansion clearance on each bar.

Overfire air. Spreader stokers burn at least 60 percent of the volatile matter in the coal in suspension in the furnace. To ensure complete combustion of the suspended material, adequate turbulence within the flame envelope must be maintained. This turbulence is provided by the use of high velocity jets of air at various levels in the furnace. This is called the overfire air system (OFA). Basically, there is one row of overfire air nozzles across the rear wall about 20 in. above the grate surface. The maximum air pressure in these nozzles is about 15 in. It is recommended that this row be operated virtually wide open for the loads normally carried. There is a row of nozzles under the feeders (2 per feeder). These jets of air were intended to help drive coal dust away from the front wall and the feeder openings. The minimum air pressure in these nozzles should be about 10 in. The influence of the rear OFA is to drive the flame forward, causing the flame to roll and creating the necessary mixing of the combustible material. The minimum air pressure in these nozzles should be about 10 in.

One last use of the OFA system is to return fly-ash from the HTWG backpass to the furnace. This is the ash reinjection system. The basic purpose of this system is to

keep this gas pass of the heater empty of fly-ash so as not to interfere with the normal flow of gas over the heating surfaces of the HTWG. To assure that this system is keeping the pass empty of fly-ash, the static pressure in this air manifold should be kept over 10 in.

Plant personnel repaired the overfire air nozzle problems discussed in Chapter 3 and replaced the entire fly ash reinjection system and the overfire air lines.

Opacity meters. The opacity meters located at the multicyclone outlets should be used to monitor the condition of the fire in the furnace. The monitors indicate the amount of fly-ash present in the flue gas stream. The opacity at the outlet of the multicyclone collectors should be about 25 percent opacity near full HTWG capacity. This will increase as the load drops because the efficiency of the unit also drops. Operators should make a graph of the opacity, temperature, and oxygen content at several HTWG loads during good operating conditions to provide a standard to check the day-to-day stoker operation. Careful attention to the operation of the combustion equipment will avoid the production of fly-ash particles that can overload or damage air pollution control equipment.

The opacity meters are subject to erroneous readings due to dust buildup on the glass shields protecting the sensors. The dust buildup will occur more frequently if the duct is under a positive pressure. Accordingly, the glass surfaces should be cleaned frequently. In addition, the meter readings can be influenced by misalignment of either component.

Minor repairs were also made to the grates to improve the operation. Middle grate clips were removed to allow for proper expansion of grate clips when heated during operation. A minimum opening space of 1 in. is required in the cold position when all grate clips are pushed to one side of the grate. This 1-in. space is required for expansion. Warped grate racks (T-Bars) were bent back to their correct horizontal position. Because this is a reoccurring problem, it should always be checked during downtimes.

Draft Control

As part of a previous initiative, new individual HTWG draft control units were installed by DCSC to control the furnace draft at the individual HTWG I.D. fan dampers. The old draft control system could not control draft because repair parts were no longer available from the manufacturer. This will improve air infiltration by controlling the furnace pressure to 0.01 in. of water (suction).

Multiple Cyclone Collectors

The efficiency of multiple cyclone collectors is influenced by the velocity of the flue gas flow through the cyclones. The optimum gas velocity occurs when the pressure drop across the collector is approximately 2.5 to 3.0 in. water pressure. Obviously, the pressure drop and the related gas velocity through the collector will be influenced by the total gas flow. Therefore, there will be a lower pressure drop at light firing rates. Accordingly, the efficiency of the collector will drop at low firing rates. Fortunately, at low firing rates less fly-ash is carried out of the furnace because the combustion gas flow is also lower.

Poor collection efficiency can also be caused by reintrainment of ash from the hopper area because of tube pluggage, air infiltration, and high hopper ash levels. The collector hopper ash must be pulled frequently enough to keep the ash level well below the bottom of the tubes. Tube surfaces should be checked and cleaned, if necessary, during annual maintenance.

HTWG Casings

Leaks in the casing were caulked and sealed by plant personnel. Stopping the room air from leaking into the combustion chamber during operation will increase the combustion efficiency of the generator about 2.4 percent based on current operating conditions. This will produce a yearly savings of:

$$(2.4 \text{ percent}) \times (10{,}600 \text{ tons/yr}) \times (\$48.00/\text{ton}) = \$12{,}200.00 \text{ per year.}$$

Flue Gas Ductwork

The individual guillotine dampers at the HTWG I.D. fan discharge must be closed when a HTWG is not in operation. When these dampers are left open, room air is drafted through the HTWG unit and passes to the common breaching, cooling the flue gas to the point where the acid dew point is reached and destroying the ESP's internals.

The bypass stack caps must be tightly closed when a HTWG is on-line and the flue gas is going to the common breaching and on to the common ESP. If these stack caps are not tightly sealed, cold air will come in these stack caps and again reduce the flue gas temperature going to the ESP. This reduction in flue gas temperature will be so great that the acid dew point will be reached.

Ash Handling System

Past procedure was to open the ash valve on the bottom of a mechanical collector or ESP and allow the ash handling system to be in normal operation. The vacuum is on the ash handling system for a short amount of time, i.e., 2 minutes, and then the vacuum is turned off the ash handling system by the use of a vacuum breaker for 1 minute to allow the accumulation of ash in the primary separator to be dropped into the ash silo during this 1-minute time interval. When the vacuum was not on the system, it was not customary to close the ash valve on the bottom of the mechanical collector or ESP. Since the hoppers of the mechanical collectors and ESPs are under negative pressure, ambient room air would flow in through the ash pipe and up through the valves into these negative pressure hoppers. The airflow into the hopper will carry fly ash to the generator I.D. fan and contribute to erosion and air pollution at the ESP hoppers.

Plant personnel now observe when the vacuum is beginning to decrease and immediately close the ash hopper valves during the cycling of the vacuum on and off in the ash-handling system.

Table 8 outlines the short-term improvements suggested and implemented by DCSC. To provide DCSC personnel a better understanding of these improvements to operation and maintenance, USACERL developed and presented a workshop at DCSC.

Table 8. Short-term improvements.

I Flue gas ducting
I.D. Fan damper operation
Stack cap leakage
II Stoker/HTWG
Stoker/maintenance
Overfire air nozzles
HTWG casing leaks
III Coal handling system
Coal delivery/storage
Bunker operation
IV Ash handling system
Valve operation

5 Performance Evaluation

The performance of both combustion and air pollution control equipment was evaluated through a series of combustion and emission tests. The objectives of the tests were to determine the effectiveness of the short-term improvements, establish a baseline to determine the effectiveness of future improvements, and show compliance with OEPA emission regulations.

Test Procedures

There were three complete combustion and air pollutant emission tests performed with HTWG no. 2 and 3 in operation. Preliminary combustion measurements during the system inspection indicated that HTWG no. 1 was the least efficient of the 3 units. A pre-compliance test was first done to evaluate the system performance after short-term improvements had been made and to identify where further improvements could be made before the official compliance test. The second test was the official compliance test. The third test modified the normal operation by turning off the HTWG I.D. fans, using only the ESP I.D. fans.

Combustion calculations were made according to ASME Power Test Code 4.1 and air emission measurements were made following OEPA regulations. In addition to the Standard F-Factor emission rate calculation, the following methods were used to cross check emission rates: Coal F-Factor, Coal Input, Btu Integrator, Btu Indicator, ASME PTC 4.1, and water meter. These methods provide several ways to calculate heat input, which is necessary to calculate the particulate emission rate, lb/MBtu. Although the heat input plays an equally important role in the emission calculation, it is often overlooked because of the attention given to calculating pounds of particulate in the EPA regulations. By comparing the results of the emission calculations using these methods, possible errors in the emission calculation can be identified. Complete test results are presented in Appendix A.

The CHPs OEPA permit to operate, issued in 1984, limits the total maximum heat output to 167 MBtu/hr with a maximum allowable particulate emission rate of 0.16 lb/MBtu. The maximum allowable emission rate for sulfur dioxide is 1.5 lb/MBtu;

however, sulfur dioxide was not tested because the current use of 1 percent sulfur coal has not caused the limit to be exceeded.

Pre-Compliance Test

The first performance test was made after the short term improvements were implemented. The test was conducted by USACERL and contract personnel, and the test was observed by base personnel. The contract personnel included a stoker expert who assisted the HTWG operator adjust the HTWG settings during the test. The test consisted of three 1-hour ASME PTC 4.1 combustion tests and three 1-hour EPA Method 5 emission tests. Generators no. 2 and 3 and ESP no. 1 were in operation.

Table 9 summarizes the combustion and air infiltration data from the test runs. The average plant output was about 72 MBtu/hr with a combustion efficiency of about 86 percent. Figure 23 shows the air infiltration through the ductwork and ESP. As expected, the temperature and oxygen in the flue gas are inversely proportional. The graph indicates a significant amount of infiltration between the HTWG and the ESP inlet caused by leaking bypass dampers and stack caps. However, the temperature is well above the 220 °F acid dewpoint required. Again, it should be noted that the temperature must be 300 °F or higher to ensure temperature above 220 °F at the outside walls of the ESP.

Table 10 lists the emission levels calculated by the methods described earlier. The methods give very similar results, indicating that plant instrumentation was in calibration and test methods were accurate. The results indicate extremely low levels of particulate emissions, which were much better than expected. The average emission

Table 9. Pre-compliance test combustion and air infiltration data (12 January).

Parameter	HTWG #2			HTWG #3		
	Run #1	Run #2	Run #3	Run #1	Run #2	Run #3
Load (MBTU/hr)	33	32.75	34.2	37.6	38.75	38.6
Temp (F)	349.8	354.6	356.4	337	336	336.4
BEFF (%)	82.53	82.31	82.4	82.24	81.95	83.19
Oxygen (%)	7.18	7.32	7.06	8.64	9.12	6.96
CEFF (%)	86.342	86.115	86.205	85.885	85.594	86.867
	ESP Inlet			ESP Outlet		
Oxygen (%)	9.3	9.8	9.4	10.2	10	10.2
Temp (°F)	312.2	312.6	315	291.8	298.6	301.4

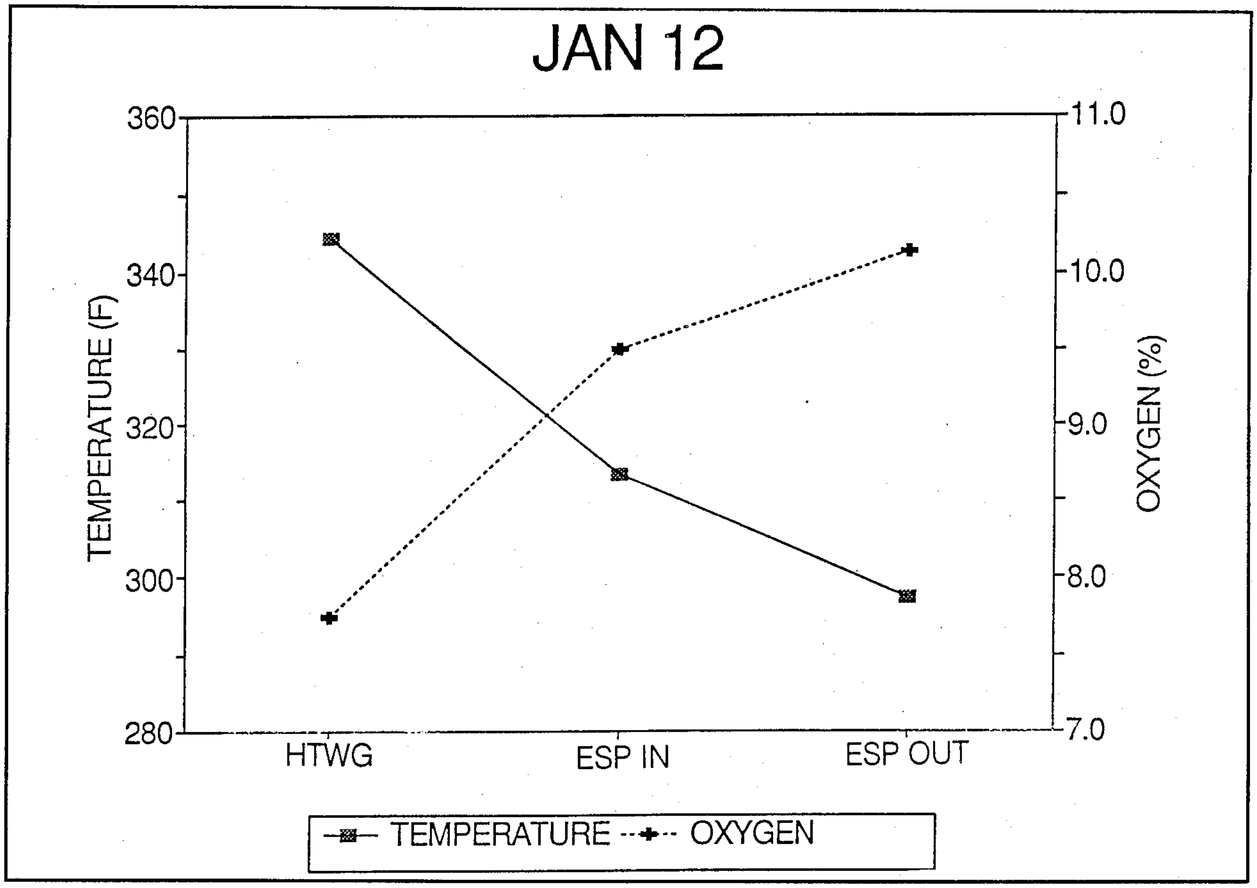

Figure 23. Pre-compliance test air infiltration.

level was 0.0248, based on measured coal input. This was about one-sixth of the Ohio EPA allowable emission level of 0.16 lb/MBtu for these operating conditions.

Official Compliance Test

An official compliance test was conducted about 1 month after the preliminary test. Generators no. 2 and 3 and ESP no. 1 were in operation. Table 11 summarizes the combustion and air infiltration data from the test runs. The average plant output was about 71 MBtu/hr with a combustion efficiency of about 85 percent. Figure 24 indicates the air infiltration through the ductwork and ESP. The graph again indicates a significant amount of infiltration between the HTWG and the ESP inlet, caused by leaking bypass dampers and stack caps. The temperature is adequate to protect against acid corrosion.

Table 12 summarizes the emission levels calculated by the methods described earlier. The results again indicate extremely low levels of particulate elisions, although they were about 50 percent higher than the preliminary test. This increase in emissions

Table 10. Pre-compliance test emission levels.

Based On	Units	Run No.1	Run No.2	Run No.3	Average
Stack	lb/hr	4.18	1.72	0.68	2.193
'F' Factor	lb/MBTU	0.0487	0.0202	0.0082	0.0257
Coal scale	lb/MBTU	0.0471	0.0198	0.0076	0.0248
% HTWG load	%	52.07%	50.86%	53.00%	51.98%
Integrator	lb/MBTU	0.0465	0.0172	0.0076	0.028
% HTWG load	%	52.70%	58.36%	53.00%	54.69%
Indicator	lb/MBTU	0.0487	0.0197	0.0077	0.0254
% HTWG load	%	50.43%	51.10%	52.00%	51.18%
ASME PTC 4.1					
Heat loss	lb/MBTU	0.0488	0.0198	0.0077	0.0254
% HTWG load	%	50.43%	51.10%	52.00%	51.18%
Water meter	lb/MBTU	0.0515	0.0221	0.0072	0.0270
% HTWG load	%	47.7%	45.4%	55.5%	49.52%
During run - blew soot		No	Yes	No	
During run-pulled bottom ash		No	No	Yes	
During run - pulled fly ash		No	No	Yes	

Table 12. Compliance test combustion and air infiltration data (12 January).

Parameter	HTWG #2			HTWG #3		
	Run #1	Run #2	Run #3	Run #1	Run #2	Run #3
Load (MBTU/hr)	28.2	28.2	26.4	44.2	44.1	43.0
Temp (F)	345.8	345.8	349.2	354.8	354.2	360.4
HTWG efficiency (%)	82.2	82.3	81.4	81.7	81.1	81.6
Oxygen (%)	7.9	7.9	8.5	9.5	9.1	9.8
Combustion efficiency (%)	85.6	85.6	84.6	85.2	84.4	84.8
	ESP Inlet			**ESP Outlet**		
Oxygen (%)	10.9	10.8	11.1	10.8	10.6	11.0
Temp (°F)	298.8	299.6	301.0	288.6	289.2	292.8

was probably due to operation by plant personnel instead of the stoker expert. The average emission level was 0.0445, based on measured coal input. This is still less than one-third the Ohio EPA allowable emission level of 0.16 lb/MBtu for these operating conditions.

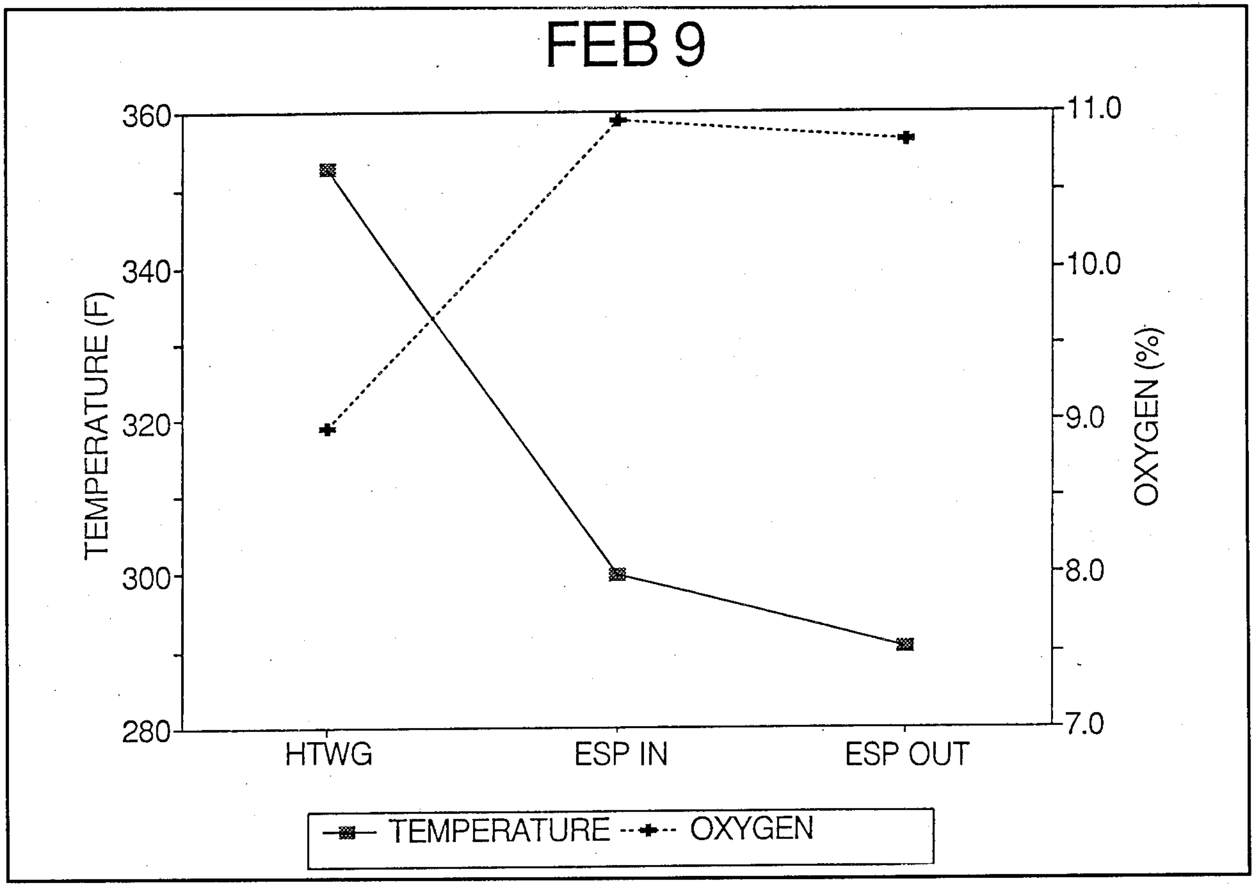

Figure 24. Pre-compliance test air infiltration.

ESP I.D. Fan Only Test

Based on operating conditions discussed in Chapter 2, it appeared that the generators could be operated without the individual generator induced draft fans, using only the ESP induced-draft fan. To test this theory, generators no. 1 and 2 were set up to operate with the individual induced draft fans off line using only the induced draft fan of ESP no. 2. Two test runs were made following the same procedures described above.

Table 13 summarizes the combustion and air infiltration data from the test runs. The average plant output was about 65 MBtu/hr with a combustion efficiency of about 86 percent. Figure 25 shows the air infiltration through the ductwork and ESP. The graph again indicates a significant amount of infiltration between the HTWG and the ESP inlet, caused by leaking bypass dampers and stack caps. The temperature is adequate to protect against acid corrosion.

Table 14 summarizes the emission levels calculated by the methods described earlier. The results again indicate extremely low levels of particulate elisions. The average emission level was 0.0350, based on measured coal input, or about one-fifth the Ohio EPA allowable emission level of 0.16 lb/MBtu for these operating conditions.

Table 12. Compliance test emission levels.

Based On	Units	Run No.1	Run No.2	Run No.3	Average
Stack	lb/hr	4.34	3.45	3.58	3.790
'F' Factor	lb/MBTU	0.0500	0.0400	0.0400	0.0430
Coal Scale	lb/MBTU	0.0488	0.0389	0.0458	0.0445
% HTWG load	%	51.84%	51.64%	45.40%	49.63%
Integrator	lb/MBTU	0.0466	0.0377	0.0396	0.0413
% HTWG load	%	54.29%	53.14%	52.60%	53.34%
Indicator	lb/MBTU	0.0489	0.0388	0.0420	0.0432
% HTWG load	%	51.71%	51.60%	49.60%	50.97%
ASME PTC 4.1					
Heat loss	lb/MBTU	0.0490	0.0389	0.0421	0.0434
% HTWG load	%	51.71%	51.60%	49.60%	50.97%
Water meter	lb/MBTU	0.0491	0.0368	0.0412	0.0424
% HTWG load	%	51.4%	54.60%	50.5%	52.17%
During run - blew soot		No	Yes	No	0.0500
During run-pulled bottom ash		No	No	Yes	0.0488
During run - pulled fly ash		No	No	Yes	51.84%

Table 13. Fan test combustion and air infiltration data (10 February).

Parameter	HTWG #2			HTWG #3		
	Run #1	Run #2	Run #3	Run #1	Run #2	Run #3
Load (MBTU/hr)	26.6	25.2		39.1	39.8	
Temp (F)	346.2	345.0		353.8	355.6	
BEFF (%)	83.4	84.1		81.8	82.6	
Oxygen (%)	7.1	6.9		8.1	9.0	
CEFF (%)	86.6	87.3		85.0	85.2	
	ESP Inlet			ESP Outlet		
Oxygen (%)	10.7	9.8		10.9	9.7	
Temp (°F)	292.4	297.0		285.4	302.2	

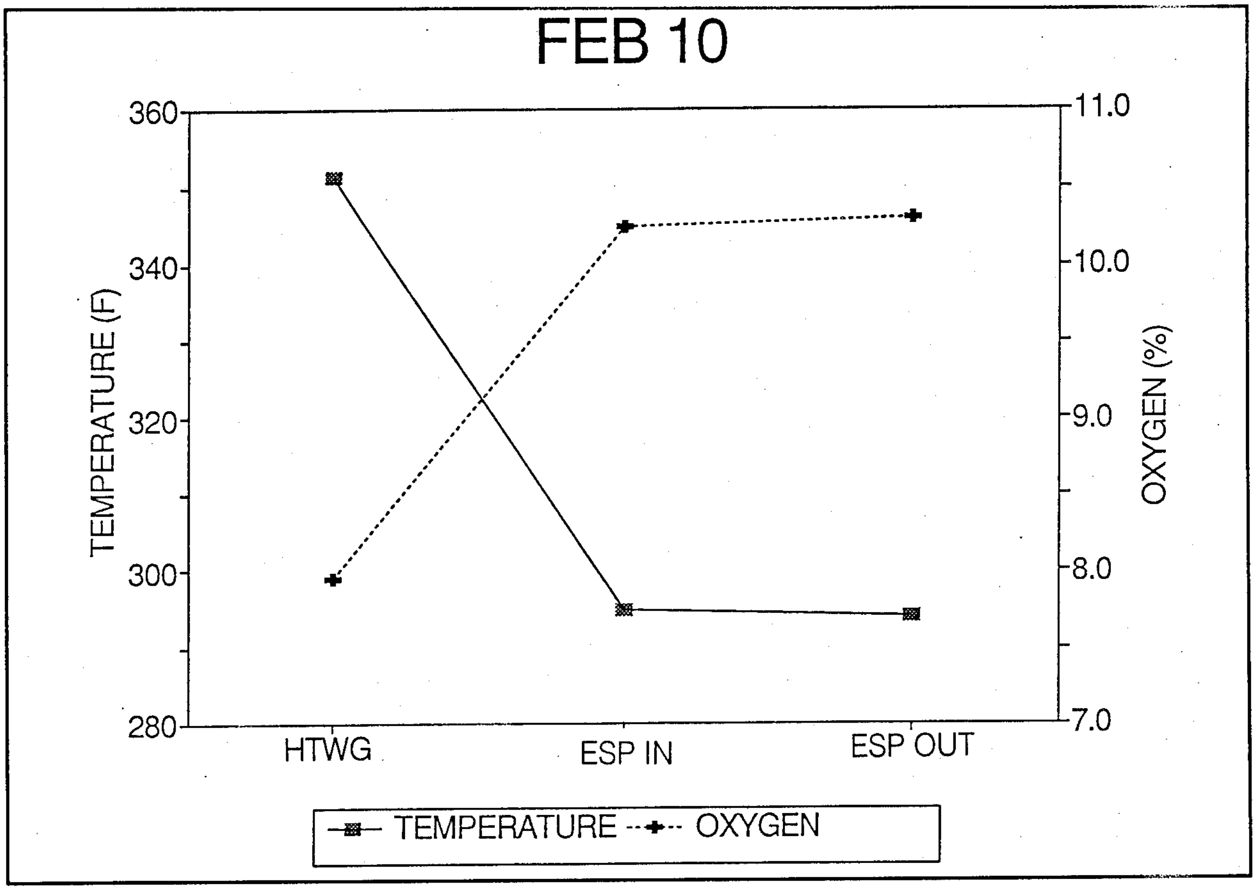

Figure 25. I.D. fan test air infiltration.

Table 14. Fan test emission levels.

Based On	Units	Run No.1	Run No.2	Average
Stack	lb/hr	3.48	2.52	2.999
'F' Factor	lb/MBTU	0.0400	0.0300	0.035
Coal Scale	lb/MBTU	0.0403	0.0296	0.0350
% HTWG load	%	50.70%	50.50%	50.60%
Integrator	lb/MBTU	0.0264	0.0275	0.0269
% HTWG load	%	77.70%	54.30%	66.00%
Indicator	lb/MBTU	0.0405	0.0299	0.0352
% HTWG load	%	50.40%	49.90%	50.15%
ASME PTC 4.1				
Heat loss	lb/MBTU	0.0406	0.0300	0.0353
% HTWG load	%	50.40%	49.90%	50.15%
Water meter	lb/MBTU	0.0403	0.0302	0.0352
% HTWG load	%	50.80%	49.30%	50.05%
During run - blew soot		No	No	
During run-pulled bottom ash		No	No	
During run - pulled fly ash		No	No	

6 Long-Term Improvements

The following chapter summarizes guidance on optimizing the performance of both combustion and air pollution control equipment to ensure long-term reliability, safety, efficiency and air quality compliance. Improvement opportunity cost estimates were prepared by Schmidt Associates, Inc. for long-range budgeting purposes. Table 15 summarizes the recommendations and estimated costs.

Coal Handling and Storage

Overhead bunker conveyor

The flight conveyor on top of the overhead coal bunker requires all drop gates to be motorized and that there be an automatic control panel for the drop gates (Figure 26). This proposed improvement will reduce segregation of coal in the overhead coal bunker and problems caused by segregation (Chapter 4). The estimated cost to modify the flight conveyor with motor-driven drop gates and controls is $130,000.00.

Under bunker conveyor

The existing under-bunker conveyor should be modified to gravity feed coal back to the bucket elevator. This will allow the plant to move coal from the overhead bunker over any HTWG to the overhead bunker over any other HTWG, a good operating option (Figure 26). This modification will allow gravity feed from the bunker to each HTWG weight scale. This mode of operation is very desirable for use over weekends. The estimated cost of modifying the existing under bunker conveyor is $30,000.00.

Spreader Stokers

Undergrate thermocouples

Operator response time to fuel-ash bed disturbances can be improved by the use of undergrate thermocouples. Early detection and correction of problems can reduce grate maintenance and extend grate life. Six thermocouples should be installed below

Table 15. Long-term improvement cost summary.

I. Stoker/HTWG	
Improve OFA system on all three (3) HTWGs	$180,000.00
Undergrate thermocouples with chart recorder @$7,000.00 per HTWG	21,000.00
New Combustion controls for all three (3) HTWGs	350,000.00
New oxygen analyzers @ $45,000.00 per HTWG	135,000.00
II. Air pollution control	
Mechanical collector improvements @$18,000.00 perl ESP	
Improvements HTWG	54,000.00
- Small purge air fan to keep insulators dry and clean on both ESPs	30,000.00
- Large purge air fan to keep off-line ESP dry and hot	70,000.00
- Thermocouples, recorders and alarms on both ESPs	18,000.00
III. Coal handling system	
Over bunker modifications	
- Twelve (12) motorized gates @ $4,000 each	
- Twelve (12) Coal splitters @ $1,200 each	48,000.00
- High level alarms and controls:	14,400.00
+ Control Panel	20,000.00
+ Twelve (12) alarms @ $1,000 each	12,000.00
+ Field wiring	26,000.00
Under bunker modifications	
- Twelve (12) Motorized gates @ $4,000 each	48,000.00
- Control panel	20,000.00
- Field wiring	18,000.00
- Additional coal chute	20,000.00
IV. Flue gas ducting	
Automation of three (3) guillotine dampers	
- Variable I.D. Fan drives (does not include motor)	45,000.00
+ Three (3) Individual HTWG I.D. Fans @$44,000 Each	132,000.00
- Two (2) ESP I.D. Fans @ $52,000 Each	104,000.00
V. Ash handling system	
Automatic sequencing controls	160,000.00
Total cost of long-term improvements	**$1,525,400.00**

the existing grates on each stoker. The temperatures of the thermocouples should be both indicated and recorded on a paper record. The cost to install six thermocouples per stoker on each generator is $25,500.00, with strip chart recorder.

Overfire air system

The design of the existing overfire air system is 30 years old. New overfire air systems provide the same 15 to 17 percent of total airflow as overfire air, but use more nozzles of smaller size, new front wall nozzles, and twice the static pressure in the overfire air

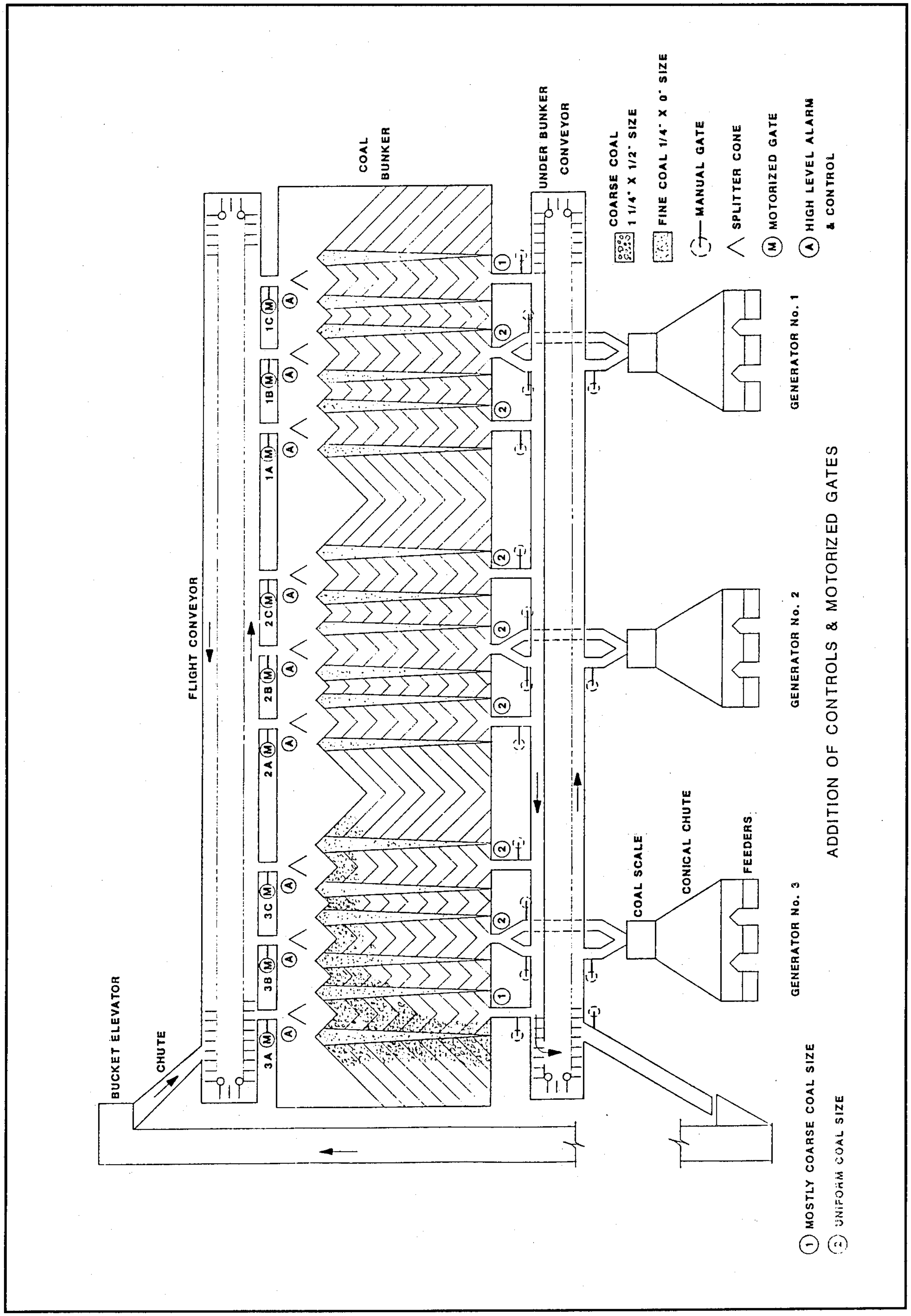

Figure 26. Addition of controls and motorized gates.

headers. This higher static pressure, with smaller nozzles, provides high velocity, which creates more turbulence over the grate in the combustion zone. The advantages of new overfire air systems are lower fly ash loading leaving the furnace, better burnout of coal, and lower total excess air.

A fully effective overfire air system requires two headers across the rear, one to serve the overfire air system and the other to serve the ash reinjection system. In addition, there should be a row of overfire air nozzles in the front wall above the feeders. To satisfy these systems, a new OFA fan would be required, with a potential of 25 in. static pressure and about twice the volume (cu. ft/min) of the present fan. The cost to install a new overfire air system per generator is $120,000.00.

Instruments and combustion controls

Spare parts are no longer available for the combustion controls and instrumentation. The system no longer functions in automatic mode and must be operated manually. The system also has no air-to-fuel ratio adjustment. The cost to install new instruments and combustion controls for all three generators is $350,000.00. The cost to install new instruments for the balance of the plant is $150,000.00.

Oxygen analyzers

Operators cannot optimize combustion efficiency without an indication of excess air in the flue gas. A zirconium oxide in-situ oxygen analyzer is the best device for determining excess air levels. Oxygen analyzers should be installed at the flue gas outlet of each generator unit. The cost to install one oxygen analyzer per generator is $45,000.00.

Flue Gas Ducting

At the time of this study, the existing induced draft fans were at the end of their useful life. The fan housings were full of holes and were effectively worn out. The existing stack caps, which are a major component of system operation, were in a difficult position for maintenance and repair.

Recommendations are to: install new induced draft fans per generator with inlet dampers for furnace draft control; install new stub stacks that are independent of the induced draft fans; install two guillotine dampers that are accessible for maintenance; install one guillotine between new induced draft fan discharge and new stub stack and one guillotine to the common breaching for both guillotines.

The cost to remove the existing induced draft fans, install new induced draft fans, dampers, ductwork, insulation, and one additional guillotine damper per generator is $810,000.00 for all three generators, not including asbestos demolition on the fans and existing ductwork.

Air Pollution Control

Multiple cyclone collectors

Although the ESP is probably capable of maintaining compliance with OEPA emission limits for particulates without the multiple cyclone collectors, they are still needed to protect the HTWG induced draft fans from erosion. The collectors should be completely rebuilt, including the cast iron collecting tubes, gaskets, locknuts, and discharge boots. The cost to rebuild all three mechanical dust collectors is $54,000.00.

Electrostatic precipitators

The ESP requires several improvements to prevent flue gas temperatures from dropping below the sulfur oxide dew points. Operation below the dew point will corrode the ESP internals causing costly repairs and increased particulate emissions.

Recommendations

- Install hot purge air fans to keep insulators dry and clean. Purge air at 350 °F or hotter.
- Install one (1) purge air fan, coil, and ductwork to serve both ESPs (at an installed cost of $30,000.00, Figure 16).
- Install large hot purge air fans (ESP I.D. fans) to keep off-line ESP dry and hot and airflow out. Purge air at 350 °F or hotter.
- Install one (1) large hot purge air fan, heating coil, hot water piping and ductwork to serve both ESPs (at an installed cost of $70,000.00).
- Accurately monitor flue gas temperatures of ESP inlet and outlet of each field.

The cost of installing thermocouples with recorder and alarms is $18,000.00 for both ESPs.

Because of the widely varying load demands, the ESP I.D. fans should be variable speed to improve combustion control and conserve electrical power. The cost to convert two 200 HP I.D. fans to variable speed is $132,000.00 for both fans.

Ash Handling System

The ash handling system needs automatic sequencing control to properly control the removal of fly ash and bottom ash. The current manual operation is labor intensive and has caused increased particulate emissions due to improper valve sequencing. The installed cost of the automatic sequencing control is $160,000.00.

7 Conclusions and Recommendations

From a detailed inspection of the central heating plant at DCSC, this study concludes that a number of faults apparently combined to cause the CHP to deteriorate and to fail USAEHA emission tests:

1. The plant was using high-carbon content coal.
2. The ESP had warped collection plates and broken discharge electrodes.
3. Coal storage practices allowed the coal to become segregated and occasionally, to spontaneously combust.
4. Grate clips showed overheating and wear, and overfire air lines were defective.
5. Excessive leaks were found in access doors, and the primary cyclone collector seal in the ash handling system was also worn.

Correcting these faults significantly improved plant operations, as indicated by the results of subsequent combustion and emission tests. To maintain those improvements, several long-term improvements are recommended:

1. The coal conveyor system needs modifications to the flight conveyor and existing under-bunker conveyor.
2. Spreader stokers need thermocouples, and new overfire air system, instrument and combustion controls, and oxygen controls.
3. The flue gas ducting needs to be replaced, and to maintain OEPA emission limits, the multiple cyclone collectors must be rebuilt.
4. The ESP needs several different improvements, especially the installation of hot purge air fans and accompanying hardware to serve the ESPs.
5. The ash handling system needs automatic sequencing control.

It is anticipated that the total cost for these improvements will be offset by the reduction in operating and maintenance costs, extension of the useful life of plant equipment, high levels of efficiency and reduction in the air-pollutant emissions.

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